RapidPLUS 8.0

Basic Course

Version 5.0.1

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esim™

Training Course

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What is RapidPLUS?

RapidPLUS

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e-SIM is the leading provider of complete MMI (Man Machine Interface) solutions to the mobile handset industry. Incorporated in millions of handsets on the market and used by major companies, e-SIM's proven MMI technology enables handset manufacturers to create state-of-the-art products and bring them to market quickly and cost-effectively.

e-SIM's MMI Solution includes an advanced MMI reference design based on a robust framework, a comprehensive set of development and customization tools, and end-to-end professional services to ensure our customers' success.

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Figure Introduction-1

RapidPLUS, the product of e-SIM Ltd., is a comprehensive software package for the generation of simulations and prototypes of electronic systems. Simulations developed with RapidPLUS, can be linked with an external programs to obtain the ultimate computer based training (CBT) solution. With ANSI-C code generation, RapidPLUS enables transformation of the virtual prototype into an executable application that can run on real embedded systems.
In general terms, RapidPLUS is an integrated development environment (IDE) for the development of Man-Machine Interfaces (MMI). The primary uses RapidPLUS include are:

- Building simulations
- Generating documentation
- Generating ANSI-C code for embedded systems

Software Packages

RapidPLUS DOC

This is the basic RapidPLUS package that enables automatic generation of documents and tests, directly from a simulation prototype. The generated documents can be in two different formats: HTML and RTF.
The intended market for this package consists of:

- Product designers
- Human interface groups
- Technical writers

RapidPLUS CODE

In addition to the RapidPLUS DOC capabilities, this package has the ability to generate ANSI-C code for the target embedded system, directly from the simulation prototype.
The intended market for this package consists mainly of embedded product developers.

RapidPLUS Web Studio

In addition to the RapidPLUS DOC capabilities, this package is used to generate a web-based simulation of the product. The package enables automatic generation of JAVA™ applets and includes a tool for creating use-case scenarios of the simulation that can run in Internet browsers.
The intended market for this package consists of:

- Marketing and sales personnel
- Web designers

RapidPLUS Xpress

This package is used for the creation of screen transition diagrams used in requirements and design specifications documents.
The intended market for this package consists mainly of user-interface designers.

Thinking RapidPLUS

RapidPLUS is a high-level development tool. It draws its power from being based on a strong state-machine. The RapidPLUS language semantics may seem familiar to experienced software developers, but it is the concept of state-machine oriented development that needs getting used to.
The RapidPLUS state-machine is defined by modes, and by transitions between these modes. The most important rule of RapidPLUS application development, is building a good set of modes, and defining the correct transitions between them.

RapidPLUS Documentation

The following manuals can be found in the Given_Resources\Manuals folder:

- Rapid Start
- Rapid User Manual
- User Manual Supplement
- Generating Code for Embedded Systems
- Methodology Guide: Building Applications for Embedded Systems
- Generating Documents
- Generating Web Simulations
- The Scenario Authoring Tool

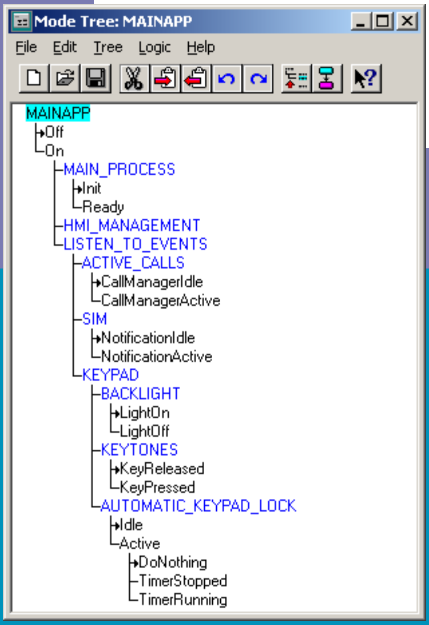
How This Book is Organized

This book is divided into five sections, each correspond to one day of the course.
Days 1 and 2 represent the process of building applications in RapidPLUS and provide some basic design methodologies.
Days 3 and 4 mainly discuss the concept of user-defined objects and their methodologies.
Day 5 concludes the course by giving an introduction on the code generation capabilities of RapidPLUS.
Appendix A, provides a brief walkthrough of the RapidPLUS tools. Appendix B provides answers to questions presented throughout the book.

Day 1

Building RapidPLUS Applications

1. Modes and the Mode Tree
2. Objects and the Object Layout
3. Transitions and Triggers
4. Activities
5. Primitive and Dynamic Objects
6. History and Special Transitions



```
MAINAPP
├Off
└On
  ├MAIN_PROCESS
  │├Init
  │└Ready
  ├HMI_MANAGEMENT
  └LISTEN_TO_EVENTS
    ├ACTIVE_CALLS
    │├CallManagerIdle
    │└CallManagerActive
    ├SIM
    │├NotificationIdle
    │└NotificationActive
    └KEYPAD
      ├BACKLIGHT
      │├LightOn
      │└LightOff
      ├KEYTONES
      │├KeyReleased
      │└KeyPressed
      └AUTOMATIC_KEYPAD_LOCK
        ├Idle
        └Active
          ├DoNothing
          ├TimerStopped
          └TimerRunning
```

Chapter 1

Modes and the Mode Tree

- Modes and Hierarchy
- Mode Tree Rules
- The Mode Tree Tool

Modes and Hierarchy

What is a Mode?

A RapidPLUS application is a description of a complete system whose overall behavior is broken down into individual modes. The modes represent different exhibited behaviors of the system. Specifically, modes separate different functionalities of the system. For example, a television can be either off or on. These are two distinct modes that represent different functionalities of the television.

Question 1-1:
Give an example of two different modes of a mobile phone.

A television actually has many other modes besides ***On*** and ***Off***. For example, when the television is on, it can be in ***Standby*** mode or ***Operate*** mode; each mode exhibits a different concrete behavior. These are distinct sub-behaviors that are exhibited when the television is on. Such sub-behaviors are referred to as *child modes* in RapidPLUS. Child modes that are under the same parent are referred to as sibling modes. For the television, the mode representing the standby behavior and the mode representing the operation behavior are sibling modes under their common parent mode, ***On***.

The Mode Tree

The parent-child hierarchy of RapidPLUS modes “branches” out, forming a tree-like structure of modes. This structure is referred to as the Mode Tree. A general behavior description (parent mode) can be divided into more concrete behavior descriptions (child modes).

The Root Mode

The RapidPLUS mode tree grows out of a single mode that is referred to as the root mode. The root mode holds all other modes and represents the most primal and general behavior of any system: its *existence*. The root mode is created automatically upon the creation of the application and by default its name is the same as the application name.

A Visual Representation

The Mode Tree visually conveys the hierarchy among the different modes of a system. Figure 1-1 shows a simple example of a television, in a RapidPLUS Mode Tree.

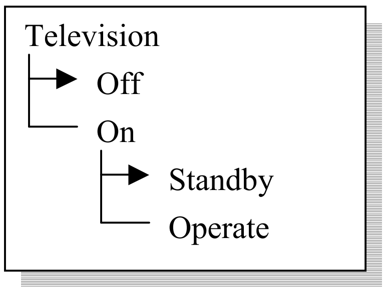


Figure 1-1: The mode tree of a television

A good mode tree is descriptive, in order to convey the logic of the system. A well-defined tree contains well-named modes, and a hierarchical and behavioral structure. Another way to look at a system's modes is through a *state chart*. Figure 1-2 illustrates the modes of the television in a state chart diagram:

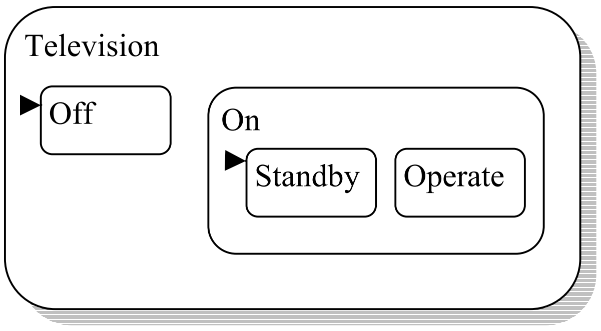


Figure 1-2: State chart diagram of the Television

Active Modes

The modes that represent the current behavior of the system are called *active modes*. There can be several active modes at any given time. For example, if the television is on and you are watching a program, both ***On*** and ***Operate*** modes are active.

Note:
The root mode is always active.

A Default Child Mode

Figure 1-1 shows two modes with arrows pointing at them: ***Off*** and ***Standby***. These are *default modes*, representing the default behavior exhibited by the television when their parent modes are active.
The root mode, which represents the television's existence, is always active (i.e., the television always exists). By default, the television is off, and as shown in Figure 1-1, ***Off*** is the default mode under the root mode.
When you turn on the television, it is in ***Standby*** mode – the default mode under ***On*** – until you instruct the television to operate.

Mode Types

RapidPLUS supports two types of modes: *exclusive* and *concurrent*. When you create a new mode generation, the default type selected for the modes is exclusive. However, you can change the selected type to concurrent.
If sibling modes are exclusive, only one of them can be active at any given time. This type of modes separates distinct behaviors that cannot be exhibited at the same time. For example, a human being cannot both sit and stand at the same time.
If sibling modes are concurrent, all of them will be active when their parent mode is active (and otherwise inactive). This type of modes is used to represent behaviors that are independent from one another. For example, a human being may stand and inhale at the same time. Neither of these behaviors is dependent on the other.
By definition, all sibling modes under a common parent mode must be of the same type.

The State of the System

In RapidPLUS, a mode represents a distinct behavior of the system, but as mentioned before, a system can exhibit several behaviors at the same time. The state of the system is thus a combination of all the active modes in the system and the status of other system elements (the system's data), at a given time.

Important:
In RapidPLUS, mode and state are not the same!

Mode Tree Rules

A RapidPLUS application must contain at least one mode: the root mode. This makes sense, because the root mode represents the system’s existence. The root mode has no siblings and is considered exclusive.
When a specific mode is activated, the following is implied:

- Its parent mode is active.
- If it has child modes, at least one of them is active.

A mode contains RapidPLUS logic that is performed when the mode is active.

The Mode Tree Tool

The Mode Tree Window

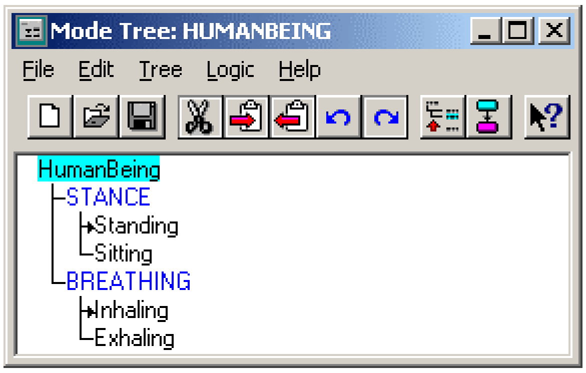


Figure 1-3: The Mode Tree window

The Mode Tree window is where you can add, remove and edit modes, and arrange the modes' hierarchy in your application. You can bring the window into focus from the Application Manager window (see Appendix part A), in one of the following ways:

- Select Mode Tree from the View menu
- Press the keyboard shortcut, Ctrl+T
- Click the Mode Tree button in the toolbar

Reading the Mode Tree

The Mode Tree provides the following visual cues:

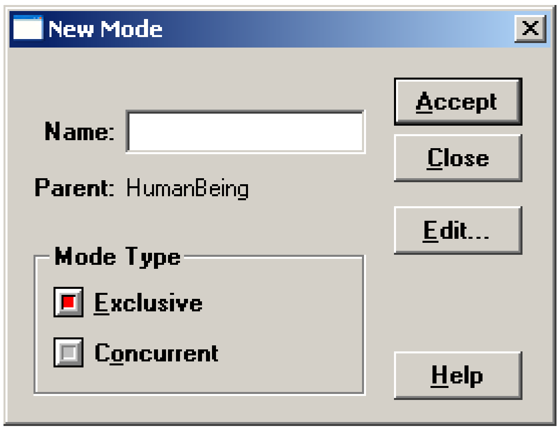
- **Exclusive modes**—are in black letters.
- **Concurrent modes**—are in blue letters.
- **Default modes**—have an arrow pointing towards them.
- **Mode in focus**—is highlighted with a cyan background. This is the mode selected for editing.

Developing the Mode Tree

The Tree menu provides the commands necessary to add, remove, edit, and arrange modes as you develop the application's mode tree. These and other commands are accessible in a popup menu by right clicking in the Mode Tree area.
To select a mode in the Mode Tree: click the mode name or use the up/down arrow keys to highlight it.

Adding a New Child Mode

1. Select a parent mode.
2. From the Tree menu, select New Mode. Alternatively you can use the keyboard shortcut Ctrl+W, or the New Mode button. The New Mode dialog box opens.



Name:

Parent: HumanBeing

Figure 1-4: The New Mode dialog box

3. Type the name of the new mode.
4. If this is the first mode under the selected parent, choose its type: Exclusive or Concurrent.
5. Click the Accept button to add the mode.
6. The New Mode dialog box remains open so that you can continue adding new modes. Click a different mode in the Mode Tree to add children under that mode.
7. When done, click the Close button.

Mode Names and Conventions

The following rules apply to mode names:

- A name can contain only letters (upper and lower case), numbers, and the underscore sign. Illegal characters are replaced with an underscore sign by RapidPLUS.
- A name must start with a letter (upper or lower case) or the underscore sign.
- Names are case sensitive, thus ***SITTING*** is not the same as ***Sitting*** or ***sitting***.
- Modes can have the same name, as long as they have different parent modes.
- The following words are reserved, and cannot be used as names: action, and, begin, clear, end, entry, exit, has, internal, is, mode, not, or, resetValue, self, subroutine, x, y.

The following mode naming conventions are recommended:

- Exclusive modes should be capitalized. If the mode name needs more than one word, each word should be capitalized, without underscores to separate the words.
- Concurrent modes should be written completely in uppercase. If the mode name needs more than one word, an underscore sign should be used to separate the words.

Editing a Mode’s Name

1. Select the mode to be edited.
2. From the Tree menu, select Edit Mode. Alternatively you can use the keyboard shortcut Ctrl+E. The Edit Mode dialog box opens.
3. Edit the mode's name.
4. Click the Accept button to confirm the change.
5. The Edit Mode dialog box remains open, so you can continue editing other modes
6. When done, click the Close button.

Tip:
You can switch between adding modes and editing existing ones from within the respective dialog boxes. In the New Mode dialog box, click the Edit button, and in the Edit Mode dialog box, click the New button.

Exercise 1-1: Developing a mode tree

Name: Television1

Description:

In this exercise you will develop a simple Mode Tree for a television.

Instructions:

1. Start a new application.
2. Save the application as Television1.rpd.
3. Build a mode tree for the application according to the following requirements (default modes are underlined):
4. The television can be either <u>***Off***</u> or ***On***.
5. When *On* it can either be in <u>***Standby***</u> or ***Operate*** modes.

Inserting a New Generation of Modes

You can add a new generation of modes in between two current generations, by inserting a mode as a child of a selected mode, while automatically making that selected mode's children, the new mode's children.

1. Select the mode you wish to be the parent of the newly inserted generation.
2. From the Tree menu, select Insert. Alternatively you can use the keyboard shortcut keys Ctrl+I. The Insert Mode dialog box opens.
3. Type the name of the new mode.
4. Select the type of the modes in the newly inserted generation.
5. Click the Accept button to insert the mode.
6. When done, click the Close button.

Removing a Mode

You can permanently remove a mode from the mode tree. The children of the removed mode, becomes children of that mode's parent.

1. Select the mode to be removed.
2. From the Edit menu, select Remove. Alternatively you can press the keyboard Delete key.

Note:

A mode can only be removed if its child modes are of the same type as it is, or if it has no siblings. This is due to the child modes becoming children of the removed mode's parent, i.e. they become siblings of the removed mode's siblings.

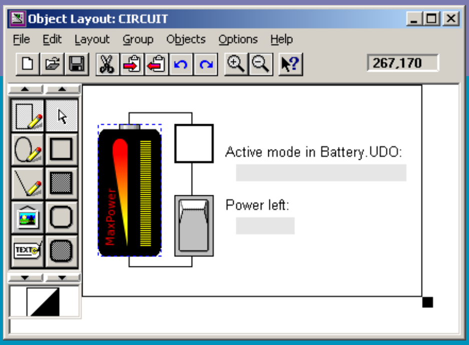
Additional Commands

You can find explanations of additional Mode Tree tool commands in the RapidPLUS User Manual or the RapidPLUS Online Help.

Exercise 1-2: Developing a mode tree

Name: Television2
Description:
In this exercise you will insert a new generation of modes to the Mode Tree you started on Exercise 1-1.
Instructions:

1. Open Television1.rpd.
2. Save the application as Television2.rpd.
3. Adapt the mode tree of the application to the following new requirements:
    - The television, being an electrical home appliance, has a power cord. This power cord can be either ***Plugged*** to a power outlet or ***Unplugged***.
    - When the television is operating, it can either display a channel or the setup program.


Object Layout: CIRCUIT
File Edit Layout Group Objects Options Help
267,170
Active mode in Battery.UDO:
Power left:
MaxPower

Chapter 2

Objects and the Object Layout

- Objects
- The Object Layout Tool

Objects

What is an Object?

As RapidPLUS applications simulate real-life systems, they need to visually represent a system's interface, and hold its internal data. RapidPLUS objects are elements of a RapidPLUS application that imitate their real-life counterparts and provide these abilities to the application.
RapidPLUS objects have pre-defined sets of properties and functions that describe how the object can behave in runtime. For example, a real lamp can either be off or on. RapidPLUS has a lamp object that exhibits the same functionality.
Unlike other visual development tools (e.g., Visual Basic™), RapidPLUS objects are used solely as elements within the code. Coding is not done within the context of an object, but within the context of a mode, or in some cases, within the context of a *transition* between modes. Transitions are discussed in Chapter 3: “Transitions and Triggers”.

Coding within the context of an object in Visual Basic™

A subroutine in Visual Basic™ for handling pressing of a button, is a good example of “coding within the context of an object”:

```
Private Sub Button1_Click()
        ‘ Handling code goes here...
End Sub
```

The Interface of an Object

Each object in RapidPLUS has its own characteristics – properties, functions and events – that allow you to control its behavior, and receive signals from it.

Properties

Each property of an object controls a specific aspect of the object's behavior. For example, a real 2-position horizontal toggle switch can be either in left or right positions. The RapidPLUS counterpart has two equivalent properties, *left* and *right*.
RapidPLUS objects also have a “self” property, designated by an ellipsis (...), which refers to the object as a whole.

Functions

Every property has functions that can either read or write that property's data, or adjust the property itself. Read and write functions manipulate the property's data, while adjustment functions manipulate the object itself. For example, both the *left* and *right* properties of the 2-position horizontal toggle switch have a *connect* function. If the left property receives the call, the lever of the switch moves to the left. If the right property receives the call, the lever moves to the right.

Events

Objects generate events to notify the application when a specific status change occurs in them. For example, when a pushbutton object is clicked, it gives the application an *in* event.

Types of Objects

There are two types of objects: graphic objects and nongraphic objects.

Graphic Objects

Graphic objects give the application its appearance and interface with the user. Graphic objects are used in the RapidPLUS logic to receive input from the user and to indicate the system's status back to the user. These objects are divided into two groups:

- **Active objects**—play an "active" role in the simulation, and can be manipulated in runtime. For example: lamps, switches, dials, displays, etc.
- **Primitive objects**—are used to enhance the appearance of the simulation, and cannot be manipulated in runtime. For example: lines, frames, labels, etc.

Nongraphic Objects

Nongraphic objects, as the name implies, have no graphic representation in runtime. They are used in the RapidPLUS logic to hold the system's data, enable time-based functionality, and support messaging between different parts of the application.
For example, a *Number* object can contain a real floating-point numeric value representing a channel frequency, while a *Timer* object can count down the seconds before the backlight on a mobile phone display turns off.

The Root Object

Like with modes, RapidPLUS objects are also arranged in a hierarchy. The topmost object in the hierarchy, parenting all other objects in the application, is the *root object*. The name of the root object is *self*, and it is sometimes referred to as the *TopPanel*. The dimensions of the root object denote the dimensions of the application, that is, the size of the application window at runtime.

The Object Layout Tool

The Object Layout Window

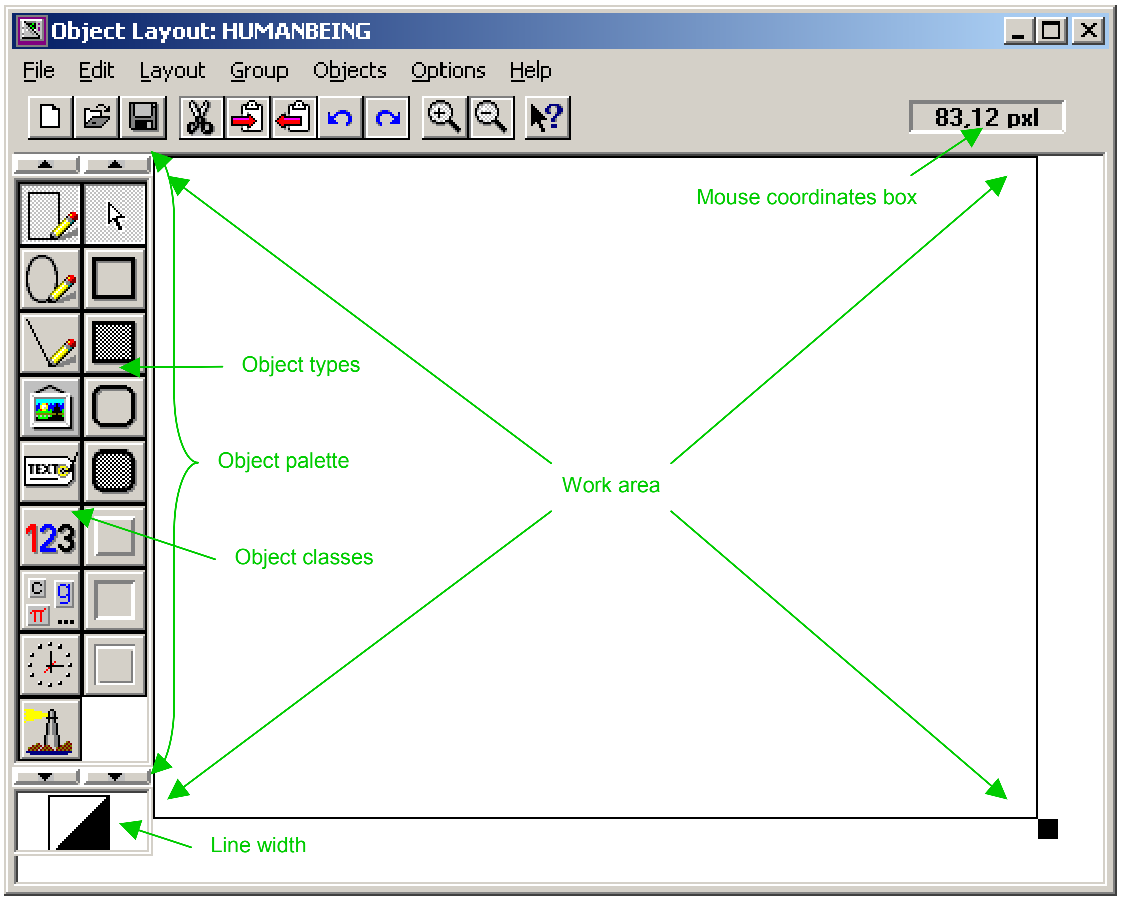


Figure 2-1: The Object Layout window

The Object Layout window is where you can add objects to your application and arrange their layout. You can bring the window into focus from the Application Manager window, in one of the following ways:

- Select Object Layout from the View menu
- Press the keyboard shortcut, Ctrl+A
- Click the Object Layout button in the toolbar

Laying Out Objects

Adding an Object

1. Select an object class from the Object palette.
2. Select the appropriate object type from that class.

3. Place the object in the work area by clicking the desired location.

Tip:
You can determine the size of an object by dragging the cursor while placing the object in the work area.

Arranging Objects

The Layout menu provides the commands for aligning, centering, distributing, and ordering of objects. These commands are useful to make a clean and appealing layout. The Group menu provides the commands for handling groups of objects. Note that objects in a group can be edited separately by selecting the group and then Edit from the Group menu. Once done, select End Edit Group from the Group menu and continue editing normally.
You can move objects around by dragging them with the cursor or by holding the Shift key and using the arrow keys. You can also resize an object by dragging its sizing handles to the required size.

Exercise 2-1: Laying out objects
Name: Layout
Description:
In this exercise you will arrange objects in the Object Layout.
Instructions:

1. Start a new application and save it as Layout.rpd.
2. In the Object Layout, add nine square pushbuttons.
3. Arrange the buttons in a 3×3 formation, equally distributed both horizontally and vertically.
4. Add a square corners filled frame behind the pushbuttons to complete the layout.

The Parameter Pane

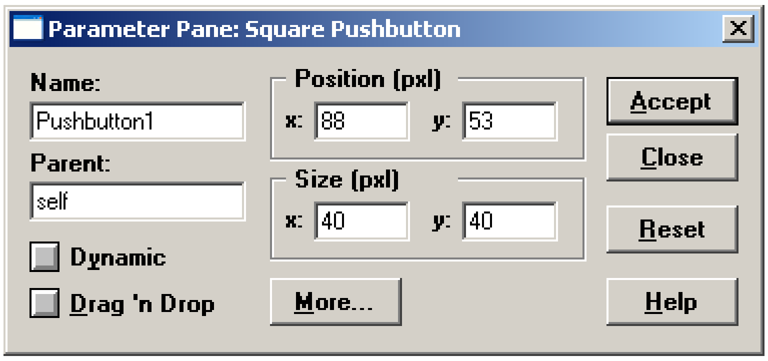

Parameter Pane: Square Pushbutton
Name: Pushbutton1
Parent: self
Position (pxl) x: 88 y: 53
Size (pxl) x: 40 y: 40

Figure 2-2: The Parameter Pane

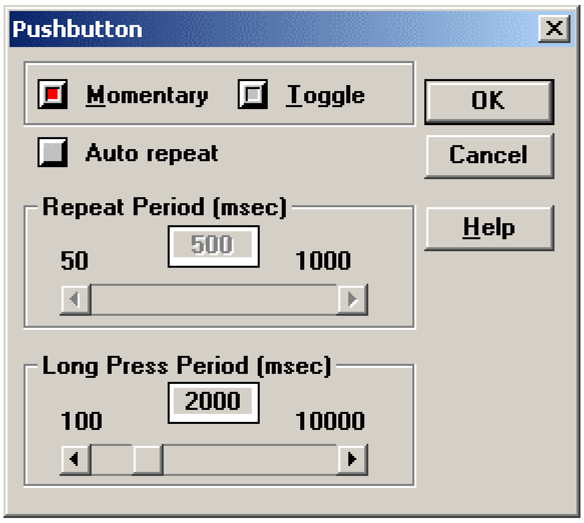
The Parameter Pane is where you set up different object parameters in design time. Double-click a graphic object to open its Parameter Pane.

In the pane you can set the following parameters:

- Name
- Parent name
- Position
- Size or Radius
- Dynamic (see chapter 5)
- Drag 'n Drop—which enables the user to drag and drop an object during runtime.

Tip:
Leave the Parameter Pane open until you finish editing all the objects. If you click an object while the pane is open, you will automatically see its parameters in the pane.

The Parameter Pane is common to all graphic objects. Object specific parameters can be set using that object's dialog box. Open the dialog box by clicking the More button in the Parameter Pane.


Pushbutton

Momentary [✓] Toggle
Auto repeat
Repeat Period (msec): 50 – 500 – 1000
Long Press Period (msec): 100 – 2000 – 10000

Figure 2-3: The specific parameters of a pushbutton object

Object naming rules and conventions

Object naming rules are the same as the mode naming rules. You can find these in chapter 1, "Mode Tree and State Machine Rules".

The following object naming conventions are recommended:

- Object names should be capitalized.
- If the object name needs more than one word, each word should be capitalized, without underscores to separate the words.
- The end of the name is concatenated with an underscore, followed by an abbreviation of the object type.

The following table lists some common objects with their abbreviation:

Object and abbreviation		**Object and abbreviation**	
Pushbutton	Pb	Display	Dsp
Switch	Sw	Number	Num
Lamp	Lmp	Integer	Int
Timer	Tmr	String	Str
Event	Ev	Array of type T	TAry
Bitmap	Bmp	Data store	Ds
Image	Img	Constant of type T	CT

Examples: Power_Pb, Status_Lmp

Additional Editing Tools

There are several other ways you can edit objects to suit your needs. You can change the line width and the colors used to draw the object, you can hide objects in design time and you can even use the Object Editor to change the complete look and feel of the object.
The Object Editor lets you edit the appearance of the object, adjust the object's active areas (its hotspots) and change the appearance of the cursor used when it is over the object.

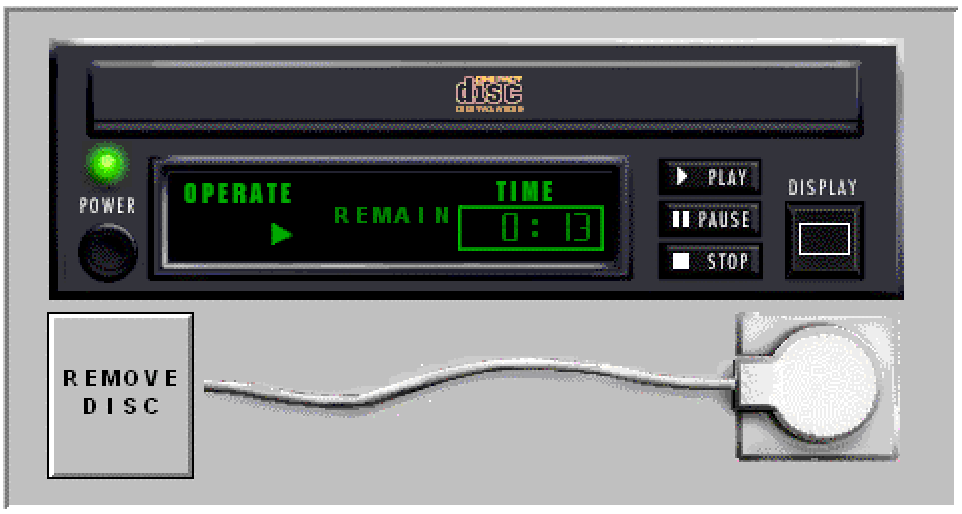


Figure 2-4: Edited objects

Figure 2-4 illustrates the usage of edited objects. The power cord for example is actually a simple horizontal slider switch. The control buttons are simple pushbuttons textured with the appropriate image.

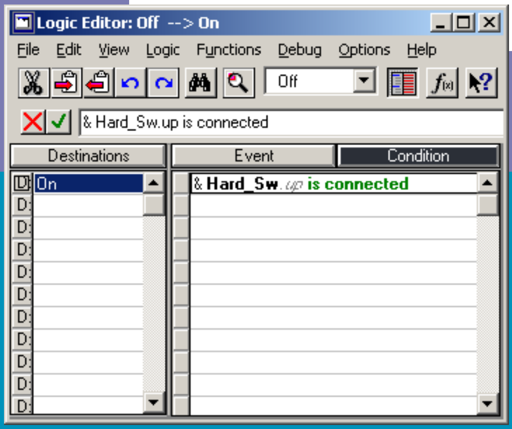
Note:
Editing objects in the Object Editor changes their graphic from vector format to bitmap format.

To learn more about editing objects using the object editor, refer to the *RapidPLUS User Manual* or the *RapidPLUS Online Help*.

Exercise 2-2: Laying out objects

Name: Television3
Description:
In this exercise you will start to give the television's front panel its appearance.
Instructions:

1. Open Television2.rpd and save it as Television3.rpd.
2. Add the following objects to the Object Layout:
   - Small round lamp.
   - A square pushbutton.
   - Rocker switch.
   - Horizontal slider switch.
3. Arrange the objects in a straight line from left to right, with equal spaces between them.
4. Name the objects according to their usage:
   - Lamp: Indicates the status of the television.
   - Slider switch: Imitates power connection.
   - Rocker switch: Used for turning the power on and off.
   - Pushbutton: Used for toggling between ***Standby*** and ***Operate***.
5. Finish the layout by adding a dark grey frame behind the objects.



& Hard_Sw.up is connected

& Hard_Sw.up is connected

Chapter 3

Transitions and Triggers

- Transitions
- Triggers
- Adding Transitions and Triggers
- Verification with the Prototyper
- Transitions and Mode Hierarchy
- Junction Transitions

Transitions

What is a Transition?

As mentioned in Chapter 1, "Modes and the Mode Tree", the system's overall behavior is broken down into modes. Each mode represents a specific behavior that the system exhibits at a given time, and the system can shift from one active mode to another. For example, when the television set is off, it can be turned on. This will deactivate the ***Off*** mode and activate the ***On*** mode. The ability to move from one mode (behavior) to another is called a *transition*.

A transition is, therefore, a route from a source mode to a destination mode. The sum of all transitions between the modes of the system represents the potential changes in the state of the system.

Graphical Representation of Transitions

In state charts, transitions are represented as arrows between the modes, originating from a source mode to a destination mode. Figure 3-1 shows the State Chart tool displaying modes with transitions between them.

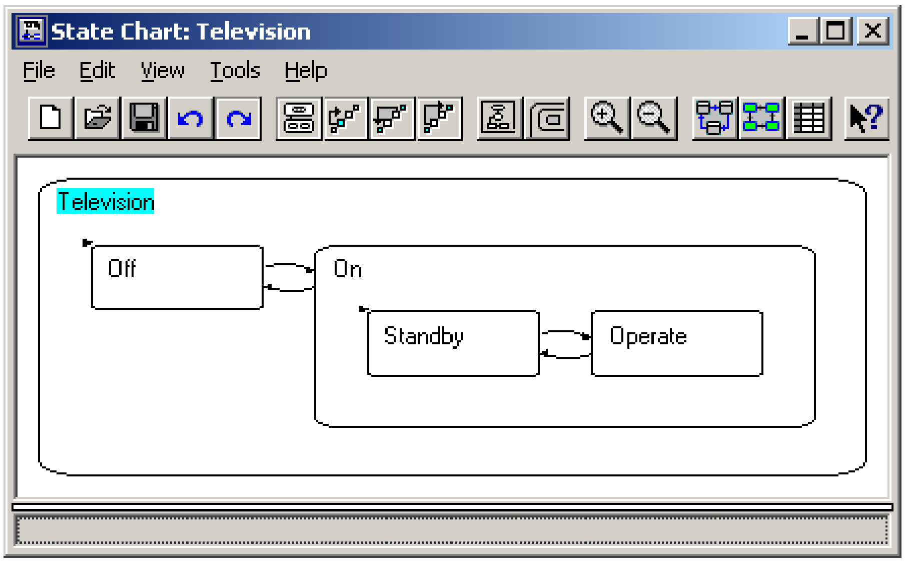


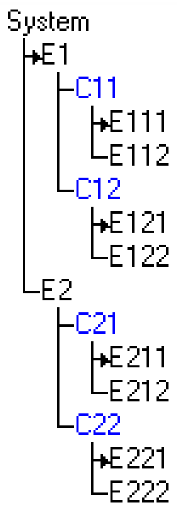
Figure 3-1: State Chart tool displaying modes with transitions

Constraints on Transitions

There are several rules regarding transitions, summarized in the following list:

- A transition can originate from any mode in the tree.
- A concurrent mode cannot be the target for a transition.
- Transitions are not allowed between concurrent branches in the mode tree.

Question 3-1:
In the mode tree to the right, exclusive modes begin with an E, and concurrent modes begin with a C. Mark the transitions that are legal.

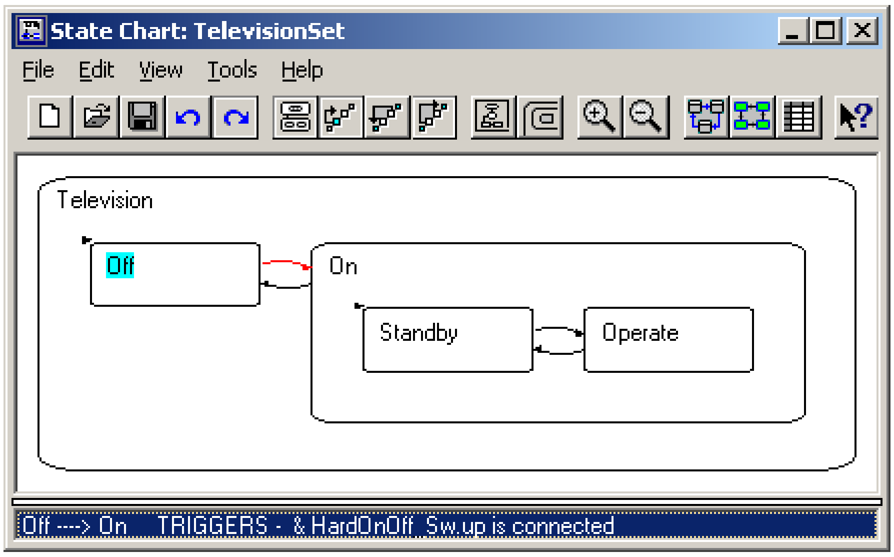


Legal	Illegal	Transition
☐	☐	E1⇨E2
☐	☐	C22⇨C21
☐	☐	E111⇨E121
☐	☐	C22⇨E222
☐	☐	E221⇨E111
☐	☐	E121⇨System

Triggers

What is a Trigger?

Transitions determine **where** the system can shift to from any given mode, but they don't tell us **why** or what causes the shift. To answer this question we attach *triggers* to the transitions. Each transition can have one or many triggers. The triggers are the reasons for executing the transition.
For example, when ***Off***, the television set can shift to ***On***. The trigger for this transition is turning the hard on/off switch on.



Off ---> On   TRIGGERS - & HardOnOff Sw.up is connected

Figure 3-2: The State Chart tool showing the trigger for a specific transition

Figure 3-2 shows the trigger responsible for the execution of the transition from ***Off*** mode to ***On*** mode. The selected transition is marked in red, and its trigger is shown at the bottom.

Types of Triggers

RapidPLUS differentiates between two types of triggers: events and conditions.

Events

An event is a notification of a change to a specific property of an object. Events are generated immediately upon the occurrence of the change. For example, when you press a pushbutton, an *in* event of that pushbutton is generated. In RapidPLUS syntax, this event looks like:

Pushbutton in

You can combine multiple events into one trigger by concatenating each event after an exclamation mark. Events cannot occur simultaneously, so for the transition to be triggered only one of the concatenated events needs to occur. In RapidPLUS syntax a trigger of multiple events looks like:

Pushbutton in ! **Timer tick**

According to this trigger, the transition is executed when a pushbutton is pressed in, **or** when a timer sends a *tick* event 9more about timers in chapter 8).

Conditions

Conditions are logical tests performed repeatedly on a property. As long as the result of the test is False, nothing happens. Once the result is True, the transition is executed. For example, the following condition tests the position of a rocker switch:

& **RockerSwitch**.*up* is connected

As long as the switch is down, the test result is False. When the switch is up, the test result is True and the trigger is executed.

Note:
The ampersand (&) is a delimiter for the start of a condition.

You can combine multiple conditions into one trigger by using logical relations such as *or*, *and*, and *not*. In RapidPLUS syntax a multiple-conditions trigger with *and* would look like:

& **RockerSwitch**.*up* is connected **and IntegerObject** > **50**

Compound Triggers

You can combine events and conditions to make one *compound trigger*. In this case, the transition will be triggered when the condition (single or multiple) is True, **and** the event (single or multiple) is generated. In RapidPLUS syntax, a compound trigger made of one event and one condition looks like:

Pushbutton in & **RockerSwitch**.*up* is connected

Question 3-2:

For each of the following triggers, when will the transition be executed?

- **Event1 ! Event2**

1. When both events take place.
2. When either event takes place.
3. Never, illegal trigger.

- **Event & Condition1 or Condition2**

1. When the event is generated and either condition is True.
2. When the event is generated or either condition is True.
3. Never, illegal trigger.

- **Event1 or Event2 & Condition**

1. When at least one of the events is generated and the condition is True.
2. When at least one of the events is generated or the condition is True.
3. Never, illegal trigger.

Events vs. Conditions

It is important to distinguish between the two types of triggers. Events occur when there is a **change** in an object's status, and immediately trigger the transition; conditions are checked repeatedly and only trigger the transition when the result is True. Table 3-1 summarizes the differences between events and conditions.

	Event	**Condition**
Definition	Notification of change to an object’s status	Check of an object’s current status
Method	Interrupt	Polling
Occurrence	Once	Continuously
Triggers	Immediately	When True
Evaluated	✗	✓

Table 3-1: Differences between events and conditions

Persistency With Conditions

Some behaviors require the specific use of conditions. For example, the requirements for a system say that when you turn a switch up, a lamp should turn on, and when you turn the switch down, the lamp should turn off.

From these requirements, you can assume that event triggers may be suitable. When you turn the switch up, an event is generated and executes a transition from ***Off*** mode to ***On*** mode. The same can be applied in the other direction.

A problem arises with a new requirement: a real lamp turns off when there is a power outage, if the switch is up when the power returns, the lamp turns on without intervention, i.e. you wouldn't need to make any changes to the system.

If you use an event as the trigger for the transition from ***Off*** to ***On***, you would have a system that doesn't act as it should, because the power coming back on will not generate the event of turning the switch up. The switch is already up.

You can solve this problem by using a condition instead of an event as the trigger for this transition. Instead of waiting for an event to be generated, you can check the status of the switch repeatedly. This way, when the power comes back on, and the up position of the switch is connected, checking the condition gives a True result—which triggers the transition to ***On***.

Adding Transitions and Triggers

The Logic Editor and Logic Palette

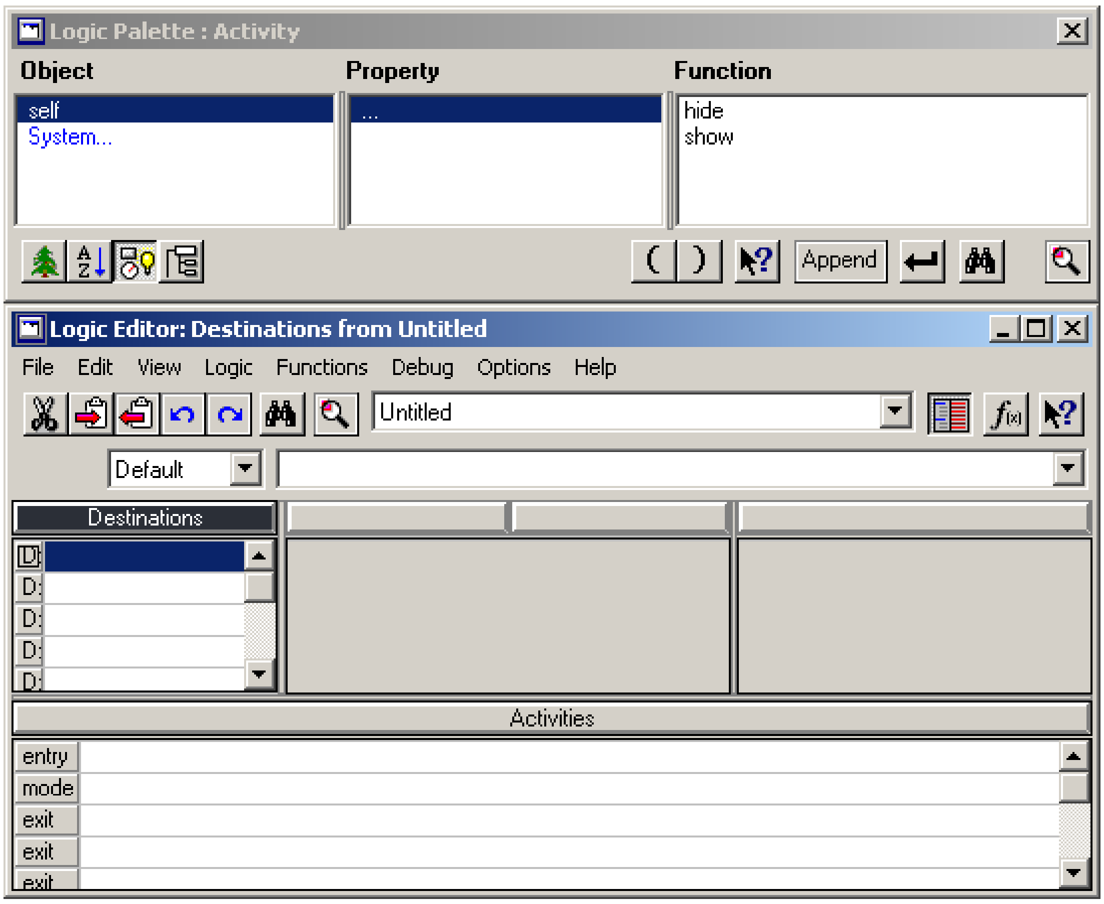


Figure 3-3: The Logic Editor and Logic Palette

The Logic Editor window is where you can write the RapidPLUS logic for your application. You can bring the window into focus from the Application Manager window (see Appendix part A), in one of the following ways:

- Select Logic Editor from the View menu,
- Press the keyboard shortcut, Ctrl+L, or
- Click the Logic Editor button in the toolbar.

The Logic Palette window is a utility window from which you can easily access the objects used in your application, their properties and their functions. You can use the Logic Palette to quickly add these elements to your application logic.

Tip:

If the Logic Palette window doesn't open automatically with the Logic Editor window, click the Logic Palette button in the Logic Editor window to open it.

Adding Transitions and Triggers

Continuing with the example of the television, you can add a transition from ***Off*** to ***On***, and an appropriate trigger.

Adding a Conditional Transition

1. In the Logic Editor, select ***Off*** from the drop-down list of modes at the top of the window. You can also select the mode by clicking it in the Mode Tree.
2. Click the first row in the Destinations column. Two drop-down list boxes appear beneath the top one. The one on the left show the word Default.
3. From the drop-down list box on the right, select the ***On*** mode, as shown in Figure 3-4.

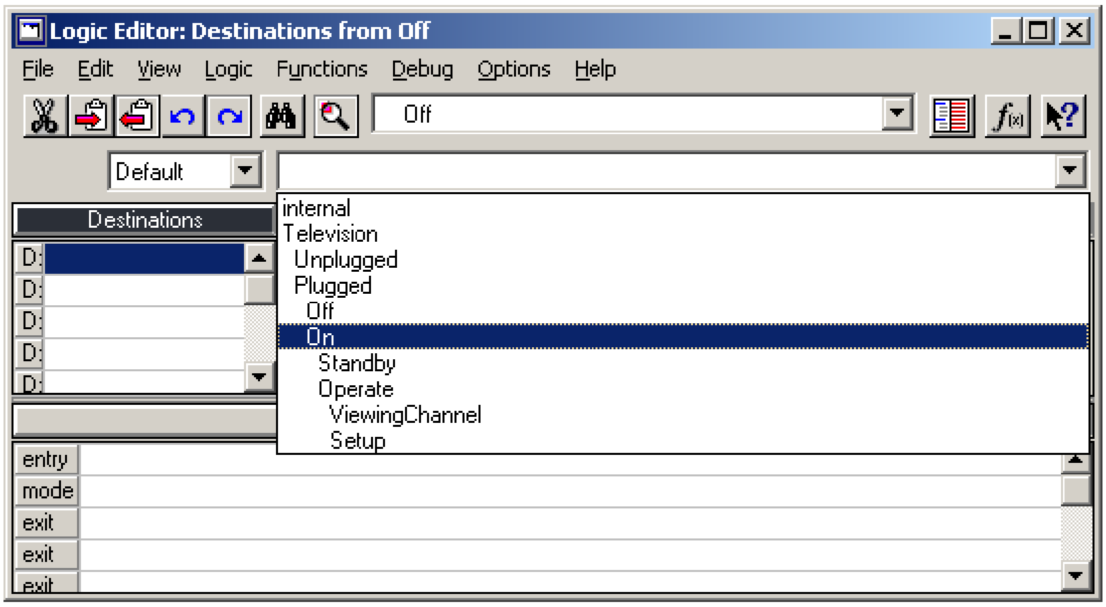


Figure 3-4: Selecting a destination mode for the new transition

4. After you select the destination for the transition, the next column in the Logic Editor is enabled; this is the triggers column. Click on Condition at the top of the column to enable the use of condition functions.
5. In the Logic Palette, double-click the Switch class in the Object column, and select the hard on/off switch. Select the *up* property and the *is connected* function.

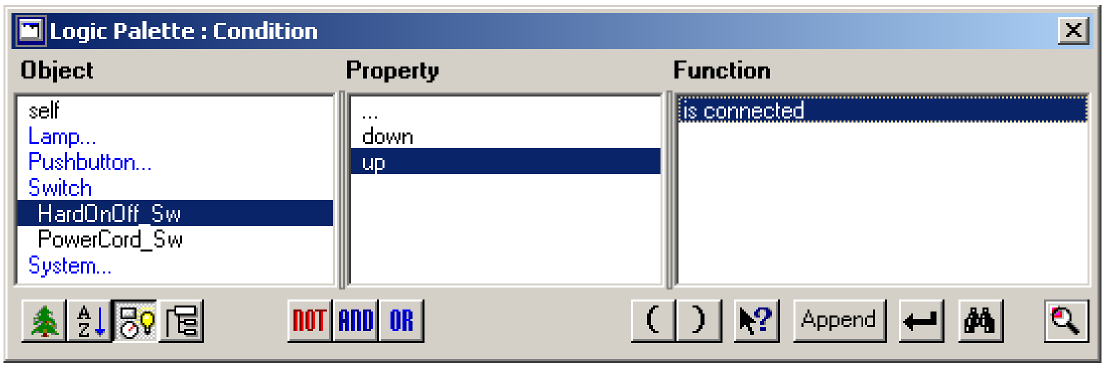


Figure 3-5: Selecting the appropriate trigger

6. Click the Append button in the Logic Palette. This appends the correct syntax of the condition to the triggers column in the Logic Editor. Figure 3-6 illustrates the finished transition.

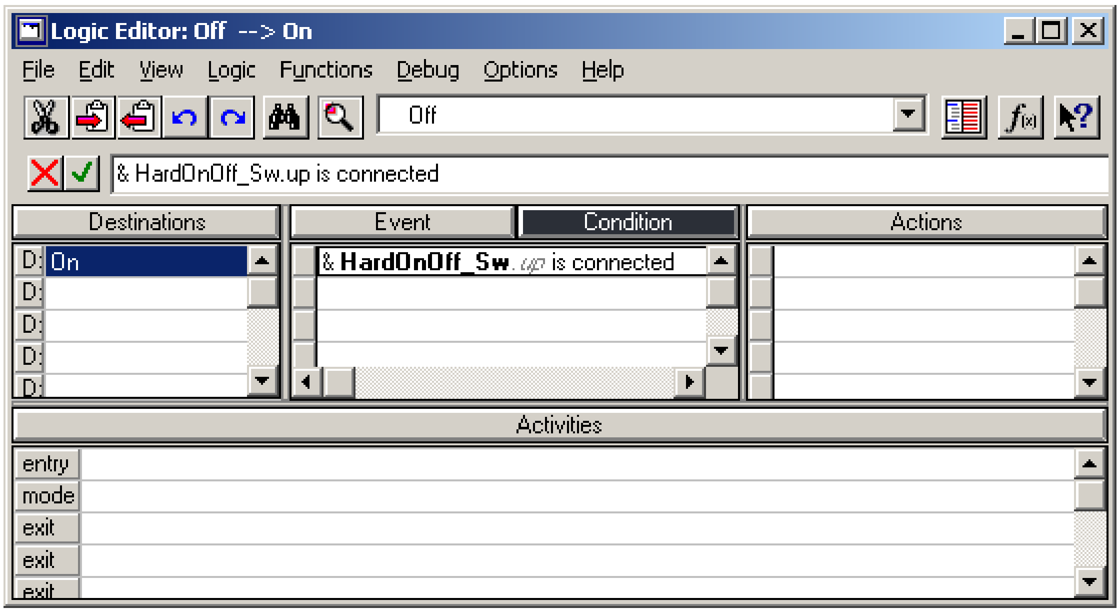


Figure 3-6: The transition from ***Off*** to ***On*** along with its trigger

Adding Other Triggers to the Same Transition

As mentioned before, a transition can have more than one trigger attached to it. In order to add another trigger to the same transition, not as a combination, but as a completely different trigger, simply select the next row in the triggers column, click Event or Condition, and repeat steps 5 to 6.

Tip:

You can activate the Logic Editor, ready to add new transitions from a selected mode. First, select the mode in the Mode Tree, and then click the New Transition button

Tip:
You can quickly add all the transitions between the modes directly in the Mode Tree First click the New Transition button and than add the transitions by selecting the source mode (highlighted in cyan) and Alt+click the destination modes (momentarily highlighted in magenta).

Exercise 3-1: Adding transitions and triggers
Name: Television4
Description:
In this exercise you will appropriate transitions to the television application.
Instructions:

1. Open Television3.rpd and save it as Television4.rpd.
2. Add the following transitions, and their respective triggers, to the application:
   - ***Unplugged*** ⇨ ***Plugged*** ⇨ ***Unplugged***.
   - ***Off*** ⇨ ***On*** ⇨ ***Off***.
   - ***Standby*** ⇨ ***Operate*** ⇨ ***Standby***.
3. Don't add transitions between the channel viewing and the setup modes.

Verification With the Prototyper

The Prototyper Tool

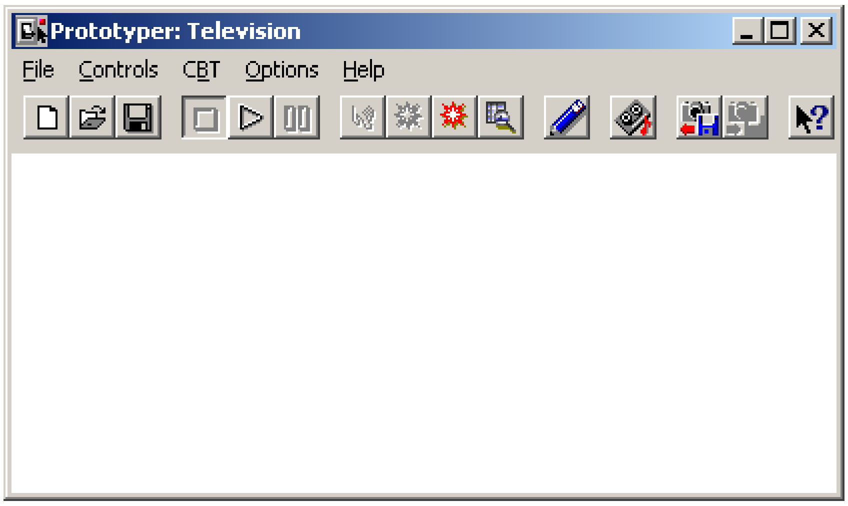


Figure 3-7: The Prototyper window

The Prototyper window is where you can verify and test your application. You can bring the window into focus from the Application Manager window (see Appendix part A), in one of the following ways:

- Select Prototyper from the View menu,
- Press the keyboard shortcut, Ctrl+R, or
- Click the Prototyper button in the toolbar.

Running the Application in the Prototyper

To run the application, select Start from the Controls menu. The state machine activates the root mode and the default child mode. For the television application, these would be the ***Television*** and ***Unplugged*** modes. The objects are shown in the Prototyper window, and you can start testing the application.

Tracing the Logic

When testing your application, you can trace the transitions between the modes. This is called *first-level debugging*.
To enable tracing, select Trace from the Options menu. When marked, this option shows the modes that are active at any given time. Notice that the root mode and some other modes in the Mode Tree window are highlighted in grey. These are the active modes. If you've just started the Prototyper on the television example, the highlighted modes should be ***Television*** (which will always be active) and ***Unplugged***.

Tip:
When developing, make it a habit to leave Trace marked.

Testing the Application

Test your application by operating it as your prospective users would. Click on the active areas of the switches and buttons, and look at the Mode Tree to see the active modes.
In the example of the television you would first plug the television to the power outlet. Use the switch that represents the power cord to do so. Notice the change in active modes. ***Unplugged*** is no longer highlighted and instead, ***Plugged*** and ***Off*** are now highlighted.

Exercise 3-2: Testing the application
Name: Television4
Description:
In this exercise you will verify the transitions and triggers you added to the television on Exercise 3-1.
Instructions:

1. Open Television4.rpd.

2. Use the Prototyper to test the application. Possible use cases:
   - Plug the system, turn it on and toggle it between ***Standby*** and ***Operate*** modes.
   - Turn the system on before plugging it and then plug it.
3. Does the system behave as expected?

Transitions and Mode Hierarchy

You can define two and more different transitions in the mode tree that use the same trigger, even two transitions from the same mode.
When a trigger is generated, the RapidPLUS state-machine passes it down the Mode Tree, through the active modes. The first mode containing a transition that uses the trigger, executes its transition. If the mode has two or more transitions using that trigger, the transition defined first in the Destinations column in the Logic Editor, is executed. In other words, transitions from modes, higher in the hierarchy, are committed first, thus overriding transitions from lower modes that use the same trigger.

Junction Transitions

Preliminary Exercise

Exercise 3-3: Junction transitions
Name: BrainTeaser
Description:
In this exercise you are required to come up with a design for a system under the constraint of using a minimal number of transitions.
Instructions:

1. Start a new application and save it as BrainTeaser.rpd
2. Construct a mode tree with three exclusive modes: ***M1***, ***M2*** and ***M3***.
3. Layout three pushbuttons and name them: Pb1, Pb2 and Pb3.
4. Add a minimal number of transitions to the system so that each button will move the system to its respective mode, e.g. Pb3 will move the system to mode ***M3***, from any source mode.

Question 3-3:
What is the minimal number of transitions required to implement a solution to Exercise 3-3?

Question 3-4:
What type or types of triggers are used in the implementation you suggested to Exercise 3-3?

What is a Junction Transition?

A common element in many applications is a switch or a series of pushbuttons that shifts the application between a series of sibling modes.
The most obvious (but not the best) solution to such a requirement is to have a transition from anyone of these modes to all the others, as illustrated in Figure 3-8.

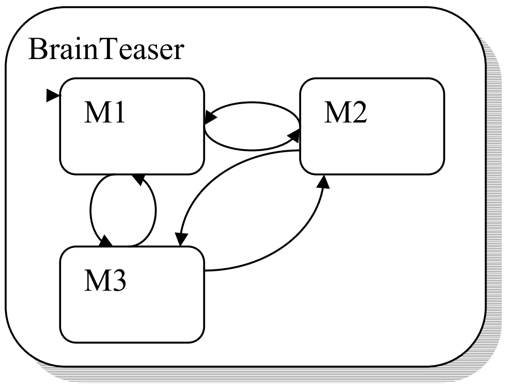


Figure 3-8: Obvious solution

This solution has a major disadvantage: the number of transitions grows in a geometrical relation to the number of sibling modes. In this example we have 6 transitions. Add another mode and the number of transitions will grow to 12. Add yet another mode and the number of transitions will grow to 20.
There is a better solution. Instead of making the transitions originate from each child, have them originating from the parent. This works because the parent mode is also active so it'll receive the trigger and execute the transition. By choosing this solution, we reduce the number of transitions to one per child mode. Adding another child will result in adding only one transition. Figure 3-9 illustrates this solution.

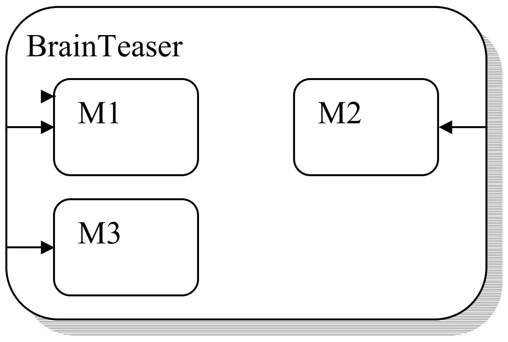


Figure 3-9: Junction type solution

Junctions Without a Default Child

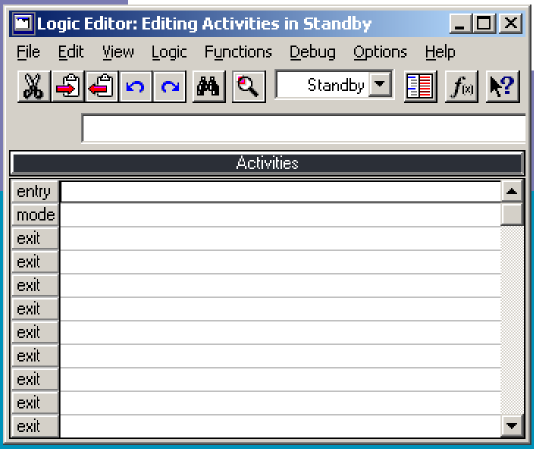
Sometimes, a special case of junction can replace the use of a default child. Take for example a system with a power switch, and a 3-stations rotary switch that selects between 3 modes of operation. When we power up the system, it should immediately be in the mode indicated by the 3-stations rotary switch. This requirement eliminates the need for a default child. Instead we use a junction from the parent mode, which in this case may be the root mode, to each and every one of the operation modes. The junction transition we are using has condition-only triggers that check the status of the rotary switch.
There are two things we need to remember about condition-only junction transitions:

- When using condition-only triggers in a junction and there is no default mode, one of the conditions must be True, when the parent mode is activated.
- Condition-only triggers from a parent tend to "lock" the system on one child when True. In order to move to another mode, the condition value must be changed.

Exercise 3-4: Adding transitions and triggers

Name: Television 5
Description:
In this exercise you are required to come up with a design for a system under the constraint of using a minimal number of transitions.
Instructions:

1. Open Television4.rpd and save it as Television5.rpd.
2. Replace the transitions between ***Off*** and ***On*** with a junction from their parent mode ***Plugged***.
3. Verify the new junction transition you made with the Prototyper.



Chapter 4

Activities

- Activities
- Adding Activities

Activities

What is an Activity?

Modes represent different behaviors exhibited by the system. If the mode names are descriptive, you can get a sense for the system behavior just by examining the mode tree. However, this is not enough. You should actually feel the behavior, not just know that it is supposed to be exhibited by the system. For example, when the system is turned on, the status LED should indicate that the system is active.
Activities are lines of logic that are added to modes and operate on the objects at runtime. The activities of a mode are executed whenever the mode is active. There are three types of activities, distinguished by the time frame in which they occur:

- **Entry activities**—occur when the mode becomes active.
- **Exit activities**—occur when the mode becomes inactive.
- **Mode activities**—occur repeatedly as long as the mode is active.

Note:
When the application is started in the Prototyper, all entry activities of all the active modes are executed. When the application is stopped, all exit activities of all the active modes are executed.

Some functions of an object can only be used as entry or exit activities and never as mode activities. For example, it makes no sense to repeatedly restart a stopwatch as long as the mode is active. The RapidPLUS stopwatch object's restart function is thus only accessible as an entry or exit activity. Other RapidPLUS objects have other functions that cannot be used as mode activities.

Adding Activities

The Activities Column in the Logic Editor

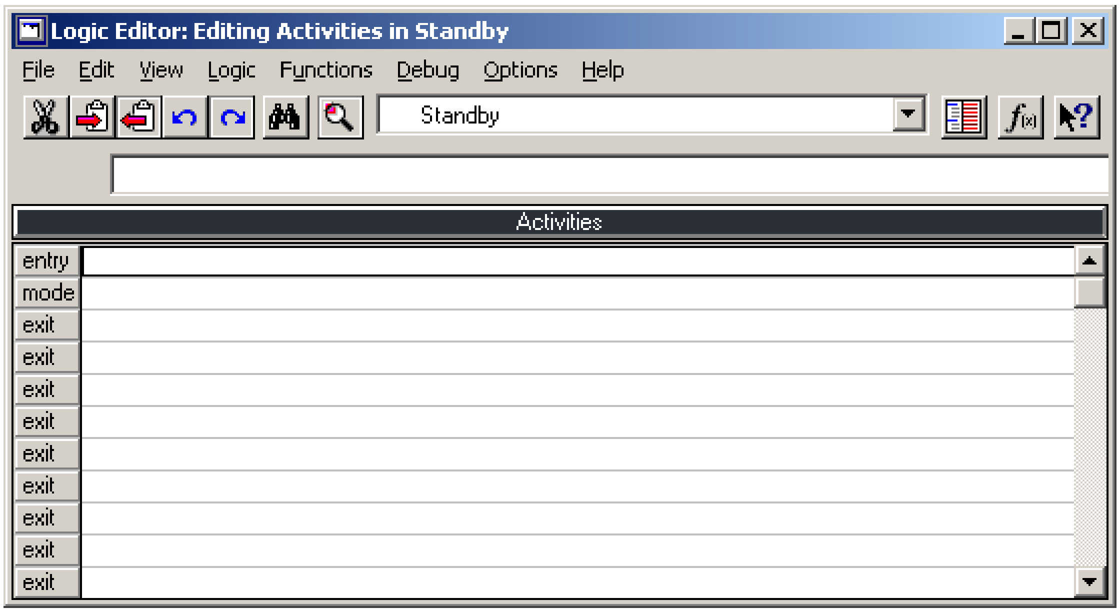

Logic Editor: Editing Activities in Standby
File Edit View Logic Functions Debug Options Help
Standby
Activities
entry
mode
exit
exit
exit
exit
exit
exit
exit
exit
exit

Figure 4-1: The Logic Editor zoomed in on Activities

Like transitions and triggers, activities are added to the application in the Logic Editor, aided by the Logic Palette.
The Activities column is beneath the Destinations and Triggers columns in the Logic editor. You can zoom in on any column by double-clicking a row in it. Figure 4-1 shows the Logic Editor window zoomed in on the Activities column. With the Activities column zoomed in, it is easier to focus on the task at hand.
As shown in Figure 4-1, the Activities column has an entry row, a mode row and several exit rows. These correspond to the three time frames in which activities take place. You can add additional rows of any type when necessary.

Adding Activities

You will now add an entry activity to the television's ***Standby*** mode. The status LED of the television should blink repeatedly while in standby. RapidPLUS lamp objects have blinking functionality. All you need to do is tell the lamp to blink, and it will do so repeatedly.

To Add an Entry Activity

1. In the Logic Editor, zoom in on the Activities column.
2. Select ***Standby*** mode from the list of modes at the top of the window. You can also select the mode by clicking it in the Mode Tree.
3. Click the first entry activity row in the Activities column to set the focus.
4. In the Logic Palette, double-click the Lamp group to expand it.

5. Select the status LED lamp, and then select the *blink* function, as shown in Figure 4-2.

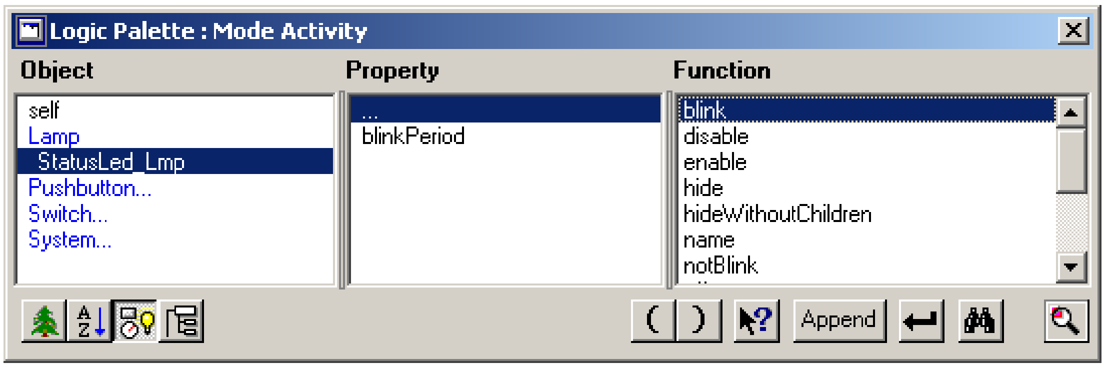
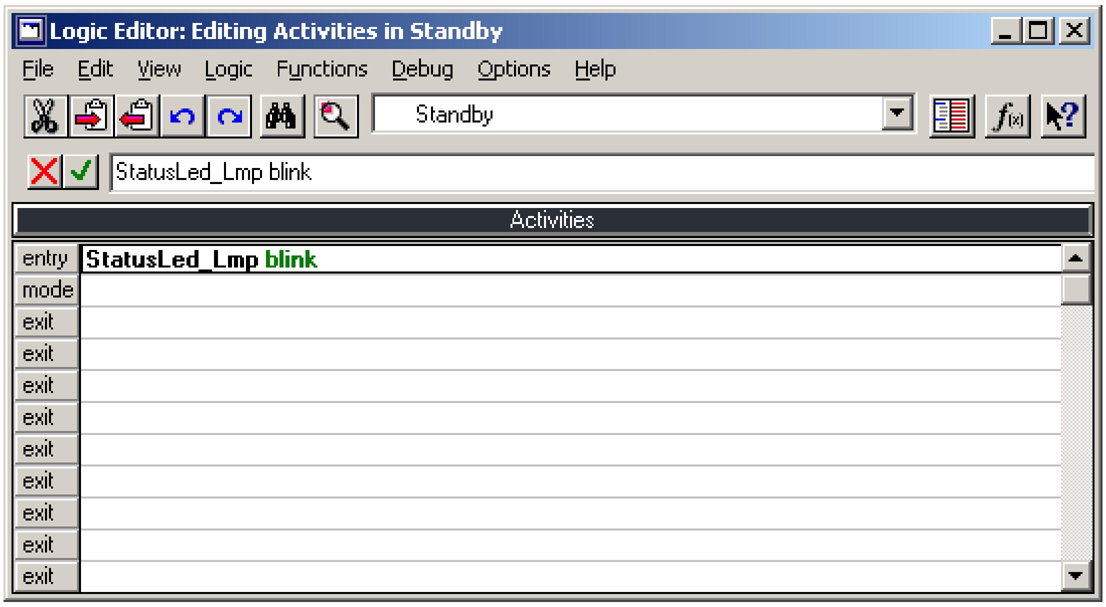


Figure 4-2: Selecting the appropriate activity

6. Click the Append button in the Logic Palette. This will append the correct syntax of the activity to the Activities column in the Logic Editor. Figure 4-3 illustrates the finished activity.


Logic Editor: Editing Activities in Standby
File Edit View Logic Functions Debug Options Help
Standby
StatusLed_Lmp blink
Activities
entry
mode
exit
exit
exit
exit
exit
exit
exit
exit
exit

entry StatusLed_Lmp blink

Figure 4-3: The entry activity for ***Standby*** mode

To Add Additional Activity Lines

As mentioned before, you can add additional activity lines when needed. These new lines can come before (above) or after (below) existing filled lines. To add a new activity line, do the following:

1. Set focus on the filled activity line you wish the new line to come before or after.
2. Add the new line as follows:
   - To add a line before the selected line, press the Insert key on your keyboard.

- To add a line after the selected line, press the Enter key on your keyboard.

Note:
The newly added line is of the same type as the line selected as a reference.

Tip:
You can change an activity's type by right-clicking the activity and selecting the appropriate type from the popup menu.

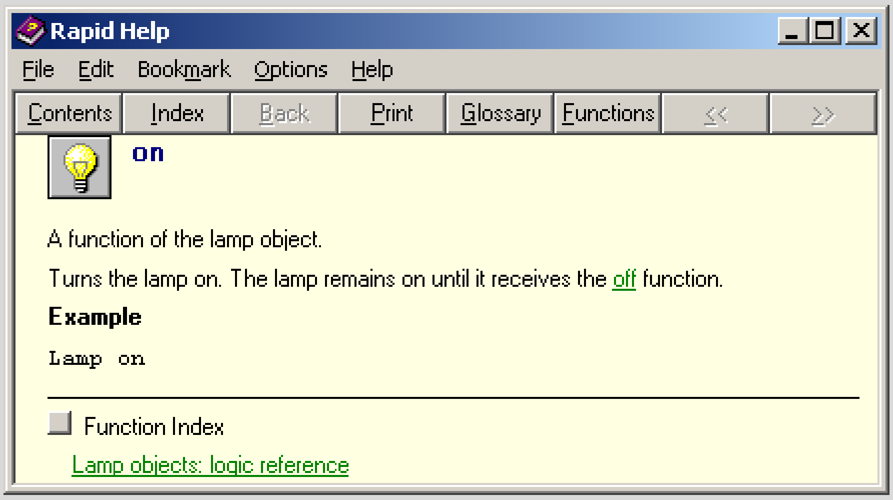
Exercise 4-1: Adding activities

Name: Television6
Description:
In this exercise you will add activities to the different modes of the television.
Instructions:

1. Open Television5.rpd and save it as Television6.rpd.
2. Add the following activities to the application:
   - When television is in standby, the status LED should blink.
   - When the television is operating, the status LED should be on.
   - When the television is not on, the status LED should be off.

Getting Help

You can get help on the different functions of an object, both trigger functions and activity functions, by selecting the function in the Logic Palette and then pressing the F1 key on your keyboard.


Rapid Help
File Edit Bookmark Options Help
Contents Index Back Print Glossary Functions << >>

on

A function of the lamp object.

Turns the lamp on. The lamp remains on until it receives the off function.

Example

```
Lamp on
```

Function Index

Lamp objects: logic reference

Exercise 4-2: Enhancing the television

Name: Television7
Description:
In this exercise you add additional activities to the television.
Instructions:

1. Open Television6.rpd and save it as Television7.rpd.
2. Adapt the application to the following new requirements:
   - The television set has a 5-character text display, for displaying information.
   - When in standby, the display shows “-----”.
   - When viewing a channel, the display shows the station’s number.
   - Other than that, the display should be blank.

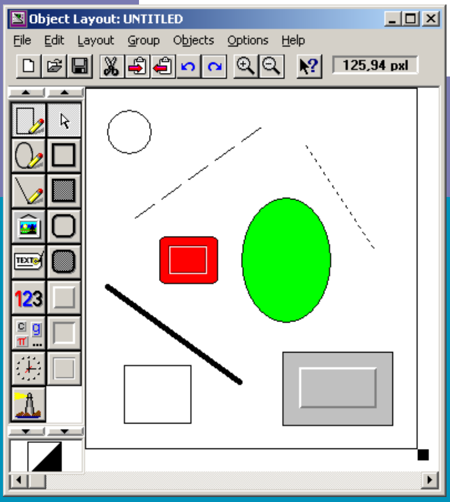
Question 4-1:

In Exercise 4-2, what property of the text display object did you use?

Question 4-2:

Answer the following questions about the television:

- Why does the status LED turn on?
- If implemented correctly, the lamp turns off when we unplug the television. Why is that?
- Does it matter where we put the lamp off activity? What options do we have?



Chapter 5

Primitive and Dynamic Objects

- Primitive Objects
- Dynamic Objects

Primitive Objects

What is a Primitive Object?

In Chapter 2, “Objects and the Object Layout,” primitive objects were defined as objects that are used to enhance the appearance of the simulation. By default, primitive objects are inactive and cannot be manipulated at runtime. However, you can make a primitive object active.

Inactive Primitive Objects

Primitive objects, by default, have no name. They are not listed in the Logic Palette, and cannot be added to the logic. Thus they are inactive, and indeed, cannot be manipulated at runtime.

Active Primitive Objects

A primitive object can be made active by giving it a name. The object is then available in the logic. However, only the basic functions, such as *show* and *hide*, are available. Figure 5-1 shows the functions of an active circle.

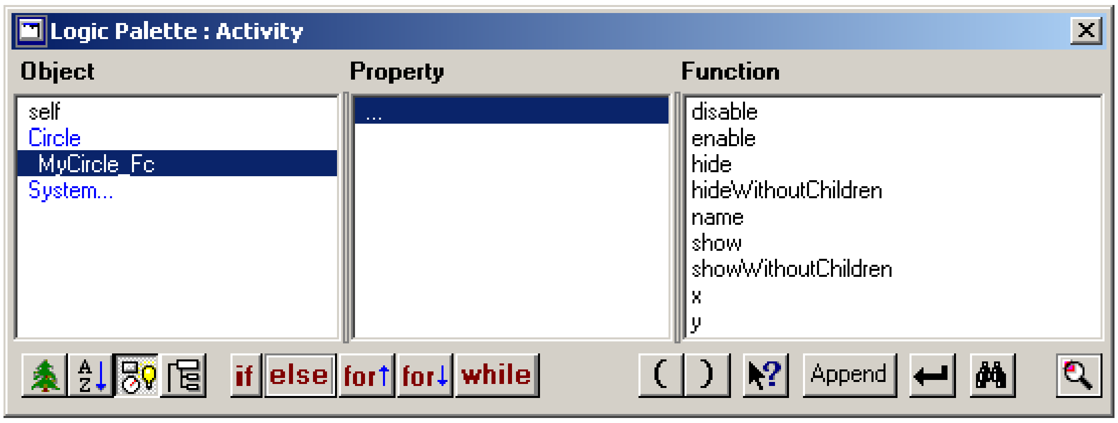


Figure 5-1: The functions of an active circle

Dynamic Objects

What is a Dynamic Object?

A dynamic object is a graphic object with additional properties that control its orientation, size, and color at runtime. To make an object dynamic, select the Dynamic property in the Parameter Pane at design time.

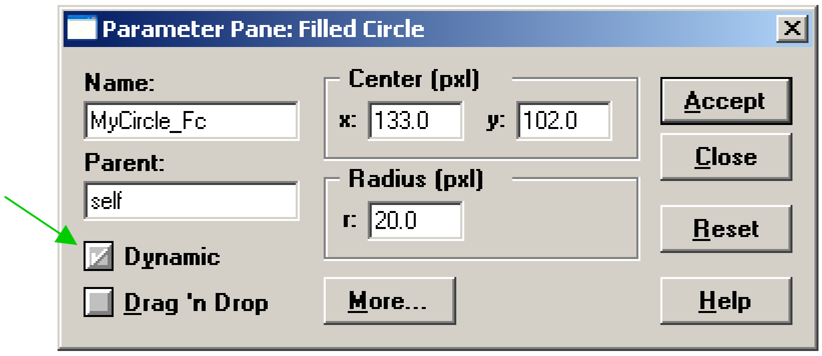


Figure 5-2: Setting the Dynamic property

Dynamic Properties

As shown in Figure 5-3, a dynamic filled circle object has five properties for controlling its center position, fill color, line color, Z-order position, and radius. Each of these properties has its respective functionality for adjusting that property's values.

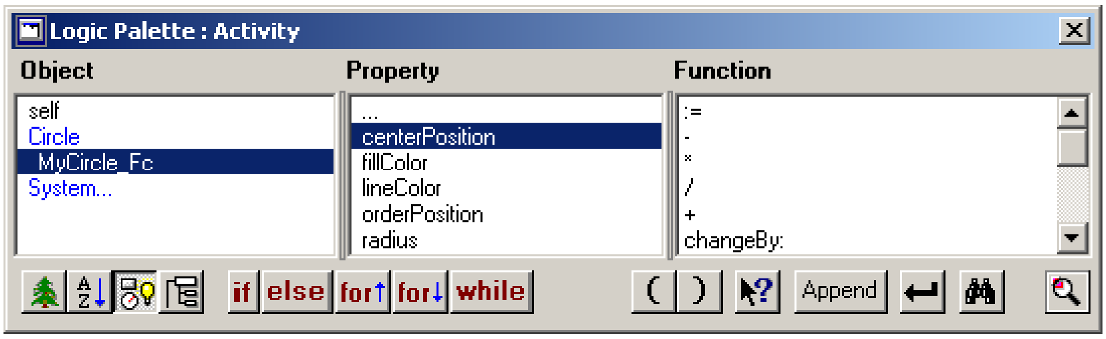


Figure 5-3: Added properties for the filled circle object

In addition to these new functions, the object becomes sensitive to click events. That is, when the user clicks it with the mouse, the object generates an event.

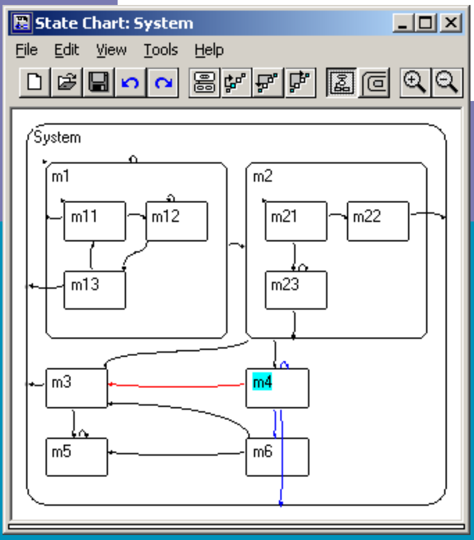
Exercise 5-1: Primitive objects and Dynamic

Name: MovingCircle1
Description:
In this exercise you will use an active dynamic primitive object.
Instructions:

1. Start a new application and save it as MovingCircle1.rpd.
2. Develop an application that meets the following requirements:
    - The system contains a filled circle and a rocker switch.
    - When the switch is down, the circle is at rest.
    - When the switch is up, the circle moves from left to right and vice versa along the X-axis, with its center position ranging from 50 at the left to 250 at the right.

3. Use mode activities to move the circle.

Question 5-1:
In Exercise 5-1, if you turn the switch off and then back on, in what direction will the circle move?



Chapter 6

History and Special Transitions

- Default and History Transitions
- Child-to-Parent Transitions
- Re-entrant Transitions

Default and History Transitions

Types of Transitions

There are three types of transitions in RapidPLUS, each marked with a different letter:

- Default transition (D)
- History transition (H)
- Deep history transition (P)

The type of transition determines which child modes will be activated upon activating a parent mode that was already active sometime in the past. The type of transition is defined during design time.

Default Transition

When a default transition is made to a parent mode, its default child is activated. This is the type of transition you have worked with so far.

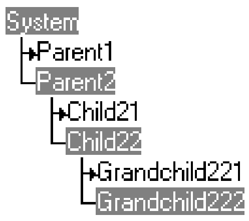
History Transition

The first time a history transition is made to a parent mode, the default child is activated. The next time the transition is made, the most recently active child mode is activated. This is not necessarily the default child.

Deep History Transition

The first time a deep history transition is made to a parent mode with several generations of descendents, the default child is activated at each generational level. The next time the transition is made, the most recently active descendant at each generational level is activated. Again, these may not be the default modes at their respective levels.

Question 6-1:
In the Mode Tree to the right, a transition is made from ***Parent2*** to ***<u>Parent1</u>***. When the transition is made back from ***<u>Parent1</u>*** to ***Parent2***, which modes will be activated for each type of transition?



- Default: ________________________________
- History: ____
- Deep history: ____

Setting the Type of Transition

You set the type of transition in the Logic Editor, while defining the transition. Figure 6-1 shows the transition type drop-down list in the Logic Editor.

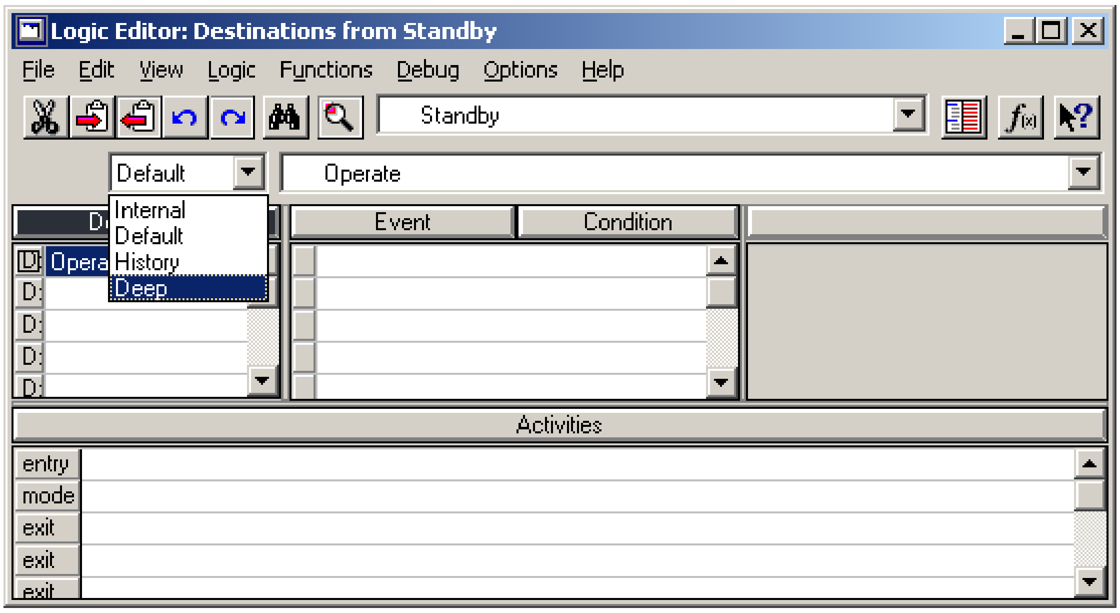


Figure 6-1: Transition type drop-down list

Exercise 6-1: Transition types

Name: MovingCircle2

Description:

In this exercise you will enhance the MovingCircle application so it'll behave in a more persistent manner.

Instructions:

1. Open MovingCircle1.rpd and save it as MovingCircle2.rpd.
2. Adapt the application so that when the circle is stopped, resuming its movement will not change its direction.
3. For additional practice in activities, adapt the application to these new requirements:
   - Add two text display objects to the application.
   - In one display, indicate the movement direction.
   - In the other display, indicate the circle's position along the X-axis.

Child-to-Parent Transitions

A transition can be made from a child mode to its parent mode or to any of its ancestors. This kind of transition is referred to as a child-to-parent transition.
A default child-to-parent transition results in activating the default child under that parent. [0]The parent's entry and exit activities are not executed, as the parent is already active. Default child-to-parent transitions are useful in situations where you would like to return to the default child from a subset of its sibling modes, without executing the parent's entry and exit activities.
A history child-to-parent transition keeps the currently active child mode active, while activating its default descendants. The entry and exit activities of both the currently active child and of the parent are not executed.
A deep history child-to-parent transition has no effect as it leaves the currently active modes, active. No activities are executed as a result of this transition.

Re-entrant Transitions

A transition can be made from a mode to itself. This is referred to as re-entrant transition. This kind of transition is useful for reset behavior.
For example, in a voice mail menu, you are told that in order to repeat the menu, you should dial 0. You do so, and the menu is repeated. This can be done over and over again. In RapidPLUS you have the menu playback function called as an entry activity of the ***Menu*** mode. As an exit activity, you call a stop playback function. A re-entrant transition triggered by dialing 0 causes the exit activities of ***Menu*** mode to be executed, stopping playback, and then causes the entry activities of that mode to be executed, restarting playback.

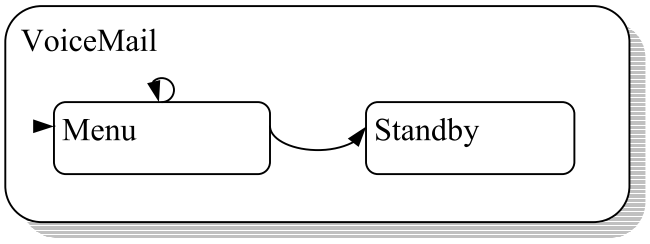


Figure 6-2: Re-entrant transition

Note:
With deep history re-entrant transitions, the same modes that were active before the transition are active after it, but their entry and exit activities are executed. This cannot be achieved with a deep history child-to-parent transition, as the state machine will dismiss the transition.

Number:
Outgoing call number:
SIM Ready PIN 1 PUK 1 Missing
PIN code 1234 PUK code 12345678
Operator long name Orange BU
Operator short name ORANGE
Operator number 42501 Network ID 1
SIM state PIN2 PUK2

Day 1 Summary

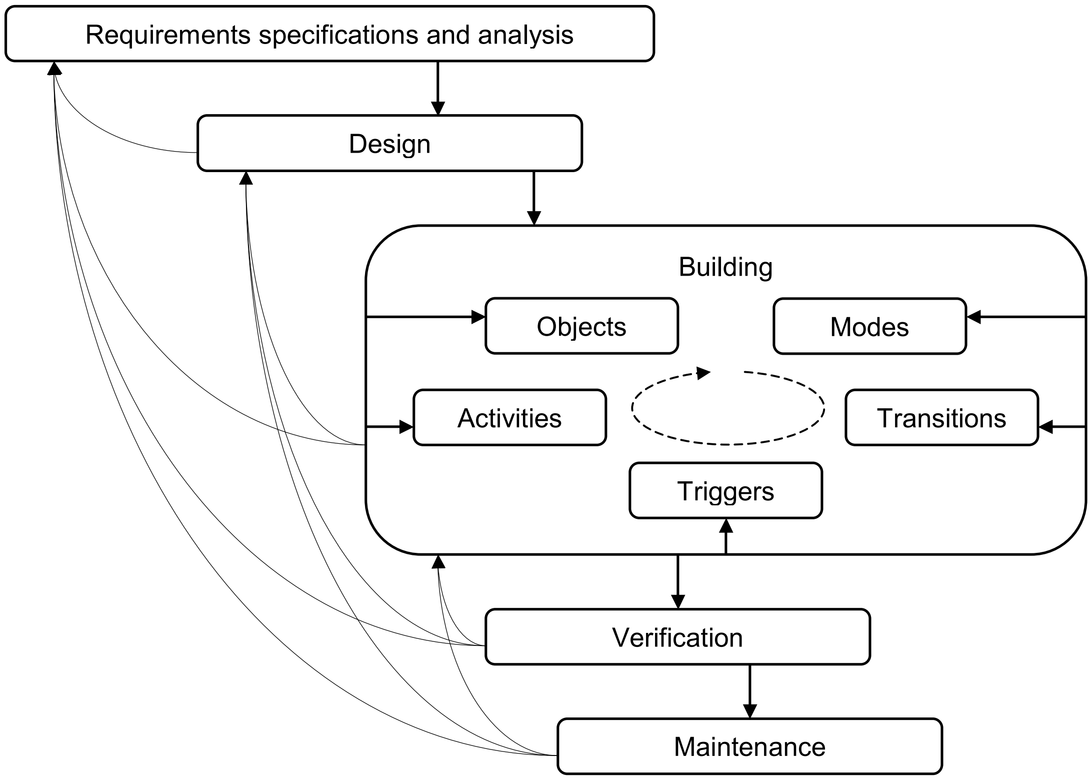
- Day 1 Recap
- Review Questions
- Summary Exercises

Day 1 Recap

Chapters 1 to 4 explored the five basic elements of a RapidPLUS application:

1. Modes
2. Objects
3. Transitions
4. Triggers
5. Activities

When we develop a new application, we first gather and analyze the requirements for the system. Then we design the system. Once we feel comfortable with our design, we start building the application.
Usually we start by laying out the different objects, as these are the most obvious elements in the application. Then we move on to building the mode tree. After that we add the transitions and their triggers, and finally the activities. This order is a suggestion, not a requirement.
If you are an experienced software developer, you know by now that requirements always change. This is why building an application in RapidPLUS is a highly iterative process.
Once all the elements are set, you will move to the verification phase and test the application, to see if all the requirements are met. If not, then it's back to the building phase. After all the requirements are met, it's time for maintenance.
The following diagram sums up the development process.



Summary of the development process: The waterfall model

[LS1]Chapter 5 talked about primitive objects and how to make them active and dynamic. This can be useful in simulations that require transformation of graphic objects.
Chapter 6 presented the three types of transitions: default, history and deep history, and explored two additional kinds of special transitions called child-to-parent and re-entrant.

Review Questions

1. When does the state machine ignore the default mode?
2. Is there a way to deactivate a mode that has no transitions to other modes?
3. Is there a way to activate a mode that has no transitions into it?
4. What are primitive objects?
5. What is the difference between an event and a condition?
6. What are entry, exit and mode activities?

Summary Exercises

Exercise 1:
Name: Smiley1
Description:
In this exercise you will develop an application according to specified requirements, using the tools you learned today.
Instructions:

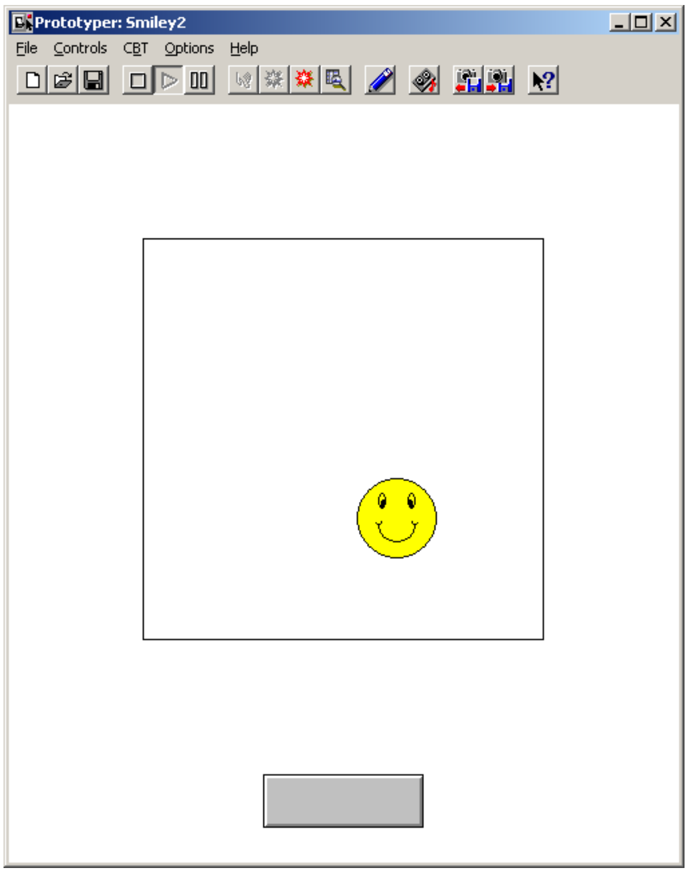
1. Start a new application and save it as Smiley1.rpd.
2. Develop the application according to the following requirements:
   - **Objects:**
     - The system contains a filled circle, an empty frame and one push button.
     - The circle's radius is 30.
     - The frame's position and size are 100@100 and 300@300 respectively.
   - **Logic:**
     - When the system starts running, the circle is resting at its home position: the top-left corner of the frame.
     - A press on the pushbutton while the circle is at home causes

the circle to start moving along the frame.

- A press on the pushbutton while the circle is moving causes the circle to freeze in place.
- A press on the pushbutton while the circle is frozen causes it to reset to home position.
- A click on the circle while it is frozen causes it to resume movement in the direction it was moving prior to freezing.
- A click on the circle while it is in motion causes it to turn 90° to the right.
- The circle cannot move outside of the frame.

Exercise 2:
Name: Smiley2
Description:
In this exercise you will add a smiling face to the circle in the Smiley application.
Instructions:

1. Open Smiley1.rpd and save it as Smiley2.rpd.
2. Add a smiling face to the moving filled circle. Use the Object Editor to do so.



Smiley2 running in the Prototyper

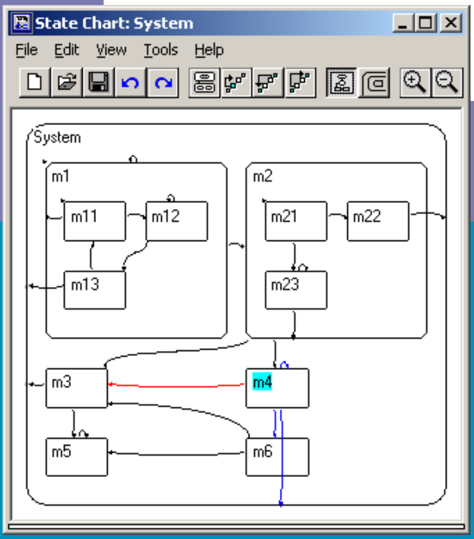
Exercise 3:
Name: Priority
Description:
In this exercise you will develop an application according to specified requirements, using the tools you learned today.
Instructions:

1. Start a new application and save it as Priority.rpd.
2. Develop the application according to the following requirements:
   - **Objects:**
     - 3 rocker switches
     - 3 Lamps
   - **Logic:**
     - Each switch controls its respective lamp.
     - Initially all lamps are off and all switches are down.
     - Only one lamp can be on at any time.
     - The <u>left</u> switch has the highest priority, while the <u>right</u> one has the lowest.
     - A lamp can be on only if its respective switch is up, and no higher priority switch is up.
   - **Limitation:**
     - Use only conditions for triggers (do not use events).
3. Provide three meaningfully different solutions.
4. Evaluate each solution according to these criteria:
   - Types of modes involved in the solution
   - Number of modes present in the solution.
   - Number of conditions used in the solution.

Number:
Outgoing call number:
SIM Ready PIN1 PUK1 Missing
PIN code 1234 PUK code 12345678
Operator long name Orange BU
Operator short name ORANGE
Operator number 42501 Network ID 1
SIM state PIN2 PUK2

Day 2

Basic Design and Additional Concepts



Chapter 7

State Modeling

- State Modeling
- Exercise

State Modeling

What is State Modeling?

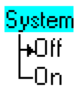
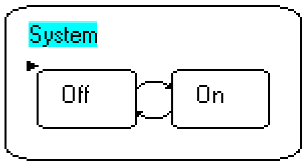
Every time we start development of a RapidPLUS application we define the different modes of the system. It is often easier to model the hierarchy and decide on the transitions when looking at the modes in a topographical manner, i.e., in a state chart. State modeling is the process of building the hierarchy of the modes and deciding on the transitions between the modes by drawing a state chart of the system.

Benefits of state modeling

A state chart outlines the logic of the system in a very easy-to-grasp way. When you build the diagram, you see the whole picture at once. It is easier to detect maintenance pitfalls and use design techniques to avoid them.

Comparing Mode Trees to State Charts

In order to clarify the differences between the two methods for representing modes and the hierarchies between them, see Table 7-1.

	Mode Tree	**State Chart**
Mode	A node in the tree	A rounded rectangle
Hierarchy	Branching	Nesting
View	Cross-section	Topographical
Transition	Invisible	Visible
Example		

Exercise

Because of the importance of state modeling in RapidPLUS development, the remainder of the chapter is dedicated to a major exercise on the topic. A detailed and explained solution to this exercise could be found in appendix part B.

Exercise 7-1: State modeling
Name: eSIMVoiceMail
Description:
In this exercise you will practice the state modeling technique by structuring a State Chart of the modes relevant for a voice mail system. You will do so according to a set of requirements.
Instructions:

1. Read the description of the system carefully.
2. Rely on your intuition to present various modes of the system in a state chart.
3. Write your solution on paper.

System description:

- By default, the system is in ***Standby*** mode.
- Every incoming call activates the system.
- Once active, the system enters the voice mail service and a welcome message is heard:

> Hello! You have reached e-SIM Ltd. Our business hours are 09:00 to 19:00, Monday to Friday.
>
> - To hear the menu options in English, press 1.
> - To hear the menu options in French, press 2.

- The system enters the English menu if the user either dials 1 or waits for 5 seconds.
- The system enters the French menu if the user dials 2.

English:	French:
• For marketing, press 1	• Pour marketing, appuyez 1
• For support, press 2	• Pour support, appuyez 2
• For training, press 3	• Pour formation, appuyez 3
• For the operator, press 0	• Pour l’accueil, appuyez 0
• To repeat this menu, press #	• Pour repeter la menu, appuyez #

- If the user dials 1, 2 or 3, the system enters the respective voice mailbox.
- If the user is idle for 5 seconds, the system enters the ***Marketing*** voice mailbox (default).

- Failure to leave a message within 10 seconds while the system is in a voice mailbox causes the system to revert to ***Standby*** mode.
- The user can dial 0 at any time in order to speak with the operator.
- When the user hangs up, the system reverts to ***Standby***.

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Chapter 8

Timer Objects

- Introduction to Time Objects
- The Timer Object
- Timer Methodology

Introduction to Time Objects

Types of Time Objects

RapidPLUS provides four types of time objects that contain different forms of time data and can be used for time-controlled operations and time-based calculations. These objects and their functions are as follows:

- **Timer**—counts down a known amount of time.
- **Stopwatch**—counts elapsed time.
- **Date**—enables easy formatting of date data.
- **Time**—enables easy formatting of time data.

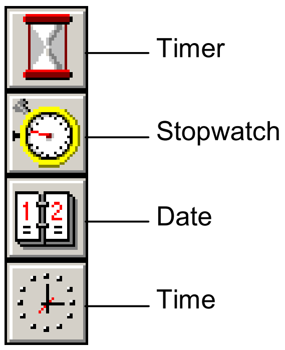


Figure 8-1: The different time objects in the Object Layout

For further information regarding the different time objects, please refer to the *RapidPLUS User Manual.*

The Timer Object

Timer Operation and Functionality

The timer object is set to count a known amount of time. It counts down from an initial amount named *initialCount* to zero. This initial amount can be represented in milliseconds, seconds or minutes. At any time, we can read the amount of time left on the timer through its *count* property. When the timer reaches zero, it generates an event called *tick*.
The timer object supports the following functionality:

Function	**Description**
stop	Stops the timer from counting. The *count* is preserved.
start	Starts counting down from the current *count* value.
restart	Starts counting down from the *initialCount* value.
reset	Stops the timer if it is running and resets the *count* value to *initialCount*.

startRepeat Starts counting down from the current *count* value. When the timer reaches zero, it restarts counting from the *initialCount* value, repeatedly.

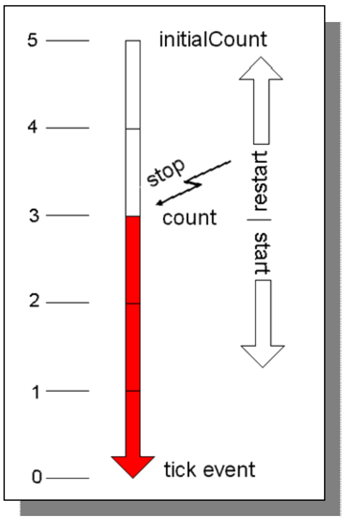
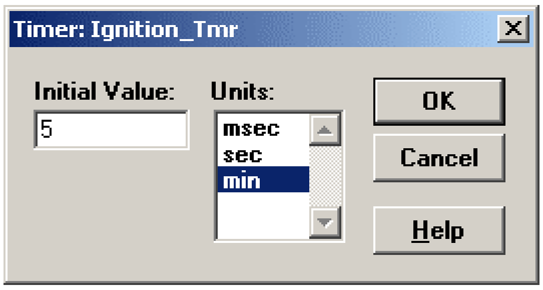


Figure 8-2: Timer object operation

To Set Up a Timer

1. Select the timer object from the Object Palette in the Object Layout.
2. You will automatically be asked for the timer's name. As timers are nongraphic objects, you do not need to place them in the layout. Give your timer a descriptive name and click the More button.
3. The Timer dialog box appears and you can set up your timer.


Timer: Ignition_Tmr

Initial Value: 5

Units: msec, sec, min (min selected)

Figure 8-3: Setting up a timer

4. As mentioned before, the timer can count milliseconds, seconds, or minutes. Select the unit from the Units list.
5. Specify the number of units you want the timer to count.
6. Click the OK button to save the settings and close the dialog box.
7. The Nongraphic Object icon appears in the Object Layout.

Figure 8-3 shows the settings for a timer that counts down five minutes.

Timer Methodology

Timer Reuse

There is no limit to the number of timers you can have in one application, but remember that, as with other elements in the application, timers come with a cost. The more timers you have, the more memory your application will use. A good habit is to reuse timers. The ability to change the *initialCount* property value makes it possible. There are two approaches to timer reuse:

- Dedicated timers.
- General use timers.

We will now examine the two approaches in detail.

Dedicated Timers

In some systems, most of the time-based operations need to count the same amount of time. In these cases you would have a timer set for that specific amount of time to serve all modes that depend on that duration. If a mode needs a different amount of time, and the timer is not in use, you can change the dedicated timer's *initialCount* in that mode's entry activity, and reset it to the common value on that mode's exit activity.

General Use Timers

Other systems may have time-based operations that do not need the same amount of time counted. In such systems, you change the timer's *initialCount* value as an entry activity in every mode that uses time-based functionality.

The Differences Between Dedicated and General Use Timers

To help clarify the differences between the two approaches, see Table 8-1.

	Dedicated	**General use**
Time count	Counts the same amount of time most of the time.	Counts different amounts of time for each behavior.
Set with a new *initialCount* value	As an entry activity of specific modes.	As an entry activity of every mode.
Reset to a common *initialCount* value	As an exit activity of the specific mode that changed it.	Never.

Table 8-1: Summary of the differences between dedicated and general use timers

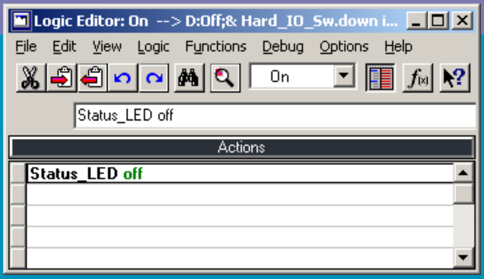
Sharing Timers Among Concurrent Modes

It is a bad habit to share timers among concurrent branches, as modes from the two branches are active at the same time. A mode from one branch may make changes to the timer, thus affecting the behavior exhibited by the concurrent branch in an undesired manner.

Exercise 8-1: Timer objects
Name: TrafficLight
Description:
In this exercise you will make use of the timer object, to control a simulation of a traffic light.
Instructions:

1. Start a new application and save it as TraficLight.rpd.
2. Build a simulation of a traffic light according to the following requirements:
    - The traffic light has three lamps: red, yellow, and green.
    - When the Prototyper is started, the red lamp is lit.
    - After 5 seconds, the yellow lamp is also lit.
    - After 2 seconds, both red and yellow lamps turn off and the green lamp is lit.
    - After 4 seconds, the green lamp starts to blink.
    - After 2 seconds, the green lamp turns off and the yellow lamp is lit.
    - After 1 second, the yellow lamp turns off and the cycle restarts with the red lamp.

Question 8-1:
If you reused a timer in Exercise 8-1, what approach did you take? If you didn't, why not?


Logic Editor: On --> D:Off;& Hard_IO_Sw.down i...
File Edit View Logic Functions Debug Options Help
On
Actions

Status_LED off

Status_LED off

Chapter 9

Internal and Transition Actions

- Transition Actions
- Internal Actions

Transition Actions

What is a Transition Action?

When a mode is activated, its entry activities are executed. Then as long as the mode remains active, its mode activities are executed repeatedly. Finally, when the mode is deactivated, its exit activities are executed. The three types of activities, entry, mode, and exit, are defined only during the time that a specific mode is active. They do not cover what happens while a transition is being executed. This is where *transition actions* come in.

Transition actions are activities that occur while a transition is executed. More than that, they only occur in the context of a specific trigger. Remember that a transition may have several independent triggers that cause its execution. Each of these triggers can be responsible for a different set of transition actions.

When To Use Transition Actions

Consider a system with three exclusive sibling modes: ***ModeA***, ***ModeB,*** and ***ModeC***. Both ***ModeA*** and ***ModeB*** have transitions to ***ModeC***. ***ModeA*** also has a transition to ***ModeB***. Two different triggers can trigger the transition from ***ModeB*** to ***Mode***C. See Figure 9-1:

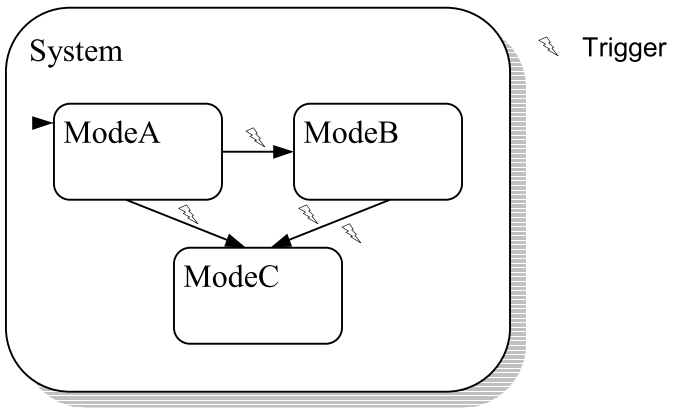


Figure 9-1: A sample system

Suppose you have an activity that you only need to execute during transitions from ***ModeA*** to ***ModeC***. Where can you put the activity?

Option	Result
Exit activity in ***ModeA***.	Executed every time ***ModeA*** is exited.
Entry activity in ***ModeC***.	Executed every time ***ModeC*** is entered.
Transition action for transition from ***ModeA*** to ***ModeC***.	Only executed during transition from ***ModeA*** to ***ModeC***.

Table 9-1: Options for placement of activities in the sample system

As you can see in Table 9-1, in the first option, the activity would be executed during transitions from ***ModeA*** to ***ModeB***. In the second option, the activity would be executed during transitions from ***ModeB*** to ***ModeC***. Only the third option—using a transition action—satisfies the requirement.
As shown in Figure 9-1, the transition from ***ModeB*** to ***ModeC*** can be triggered by one of two different triggers. Suppose you need a special activity to be executed for one trigger but not the other. In this situation, the only option is to make the activity a transition action of the relevant trigger.

Use With Care

Transition actions should only be used when they are truly needed, like in the examples above. To illustrate a problem that may arise from misuse of transition actions, consider the following simple system:
The system comprises a lamp, a pushbutton, and a power switch. The lamp can be toggled on and off by pushing in the pushbutton only when the switch is up. The system therefore has four modes. It can either have ***NoPower*** or ***Power***. When it is powered, it can either be in ***Standby***, indicated by the lamp being off, or ***Operating***, indicated by the lamp being on. It can be argued that the *lamp on* and *lamp off* activities could be transition actions between the ***Standby*** and ***Operating*** modes. This solution has one inherent problem. If the lamp is on and the power is then turned off, the lamp remains lit, because the *lamp off* activity is only executed for the specific transition from ***Operating*** to ***Standby.*** However, the transition that was triggered in this case is the one from ***Power*** to ***NoPower***.
Another issue that bears consideration is that transition actions are coupled with a specific trigger of a specific transition. They are only visible in the logic editor when focus is set to this particular transition and trigger. This means that they are not very visible when reviewing the logic. This is important to note because you can replace transition actions with more visible logic in the activities of the different modes, even though this may sometimes be less efficient.

Exercise 9-1: Transition actions

Name: MovingCircle3
Description:
In this exercise you will add new functionality to the moving circle application, using transition actions.
Instructions:

1. Open MovingCircle2.rpd and save it as MovingCircle3.rpd.
2. Adapt the application to these new requirements:
   - The system should now have a pushbutton.
   - When the pushbutton is pushed, the circle changes direction, regardless of its position.
   - If the pushbutton is pushed while the circle is moving left, the circle's fill color changes to red.
   - If the pushbutton is pushed while the circle is moving right, the circle's fill color changes to green.

Internal Actions

What is an Internal Action?

Internal Transitions

You have probably noticed by now that when you select a destination for your transition, or when you select the type of the transition, one of the destinations or types is called *Internal*, as shown in Figure 9-2.

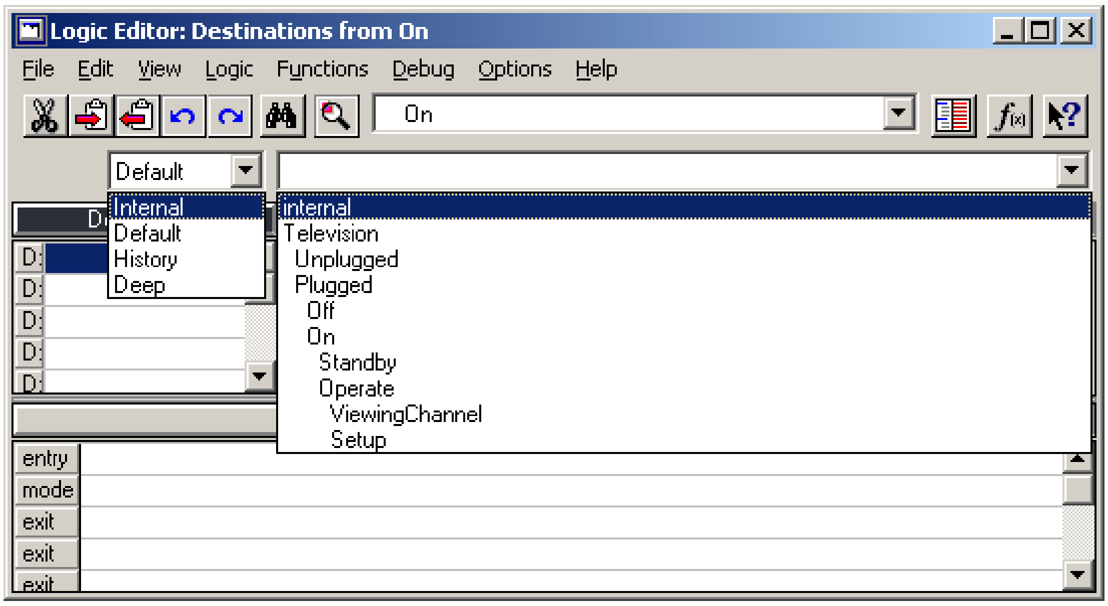


Figure 9-2: Internal destination and type in the Logic Editor window

Internal transitions represent a triggered fluctuation of status within the mode. They differ from other transitions in that when triggered, the exit and entry activities of the mode are not executed.

Important:
During internal transitions, there is no change to the status of the modes. Active modes remain active; inactive modes remain inactive.

Internal Actions

Internal transitions are used to define triggered activities that take place within the mode. These activities are referred to as *Internal actions*.
You use internal actions to make changes to objects' data and status. For example, a television has several channels. Although you can define a different mode for every channel, this is logically wrong. No matter what channel you are watching, the only difference is the data (in this case, the frequency of the channel displayed), and not the behavior. The television behaves exactly the same on each channel. In this situation, changing the channel is a triggered activity that is executed within the mode

representing the behavior of displaying a channel. The activity in this case would be changing the value of the frequency used by the receiver.

Using Internal Actions

Do Not Use Condition-Only Triggers

Condition-only triggers with internal transitions induce polling. Conditions are evaluated when there's a chance of change in the system's status, for example a change in data. If a condition-only trigger is true, the internal transition is triggered. Although this does not cause execution of the exit and entry activities of the mode, it is considered a change in the mode's activeness, i.e., the mode is activated. This in turn causes the condition to be re-evaluated. As long as the condition is true, it will be re-evaluated over and over again.
What is the difference between condition-only triggers with internal transitions as opposed to transitions with real destinations? With real destination transitions, if the condition is true, the transition causes a shift between modes in the system. The new active mode has different transitions with different triggers, so the condition is no longer evaluated.

Use Event-Based Triggers

Event-based means either event-only or compound triggers. As a rule you should only use this type of trigger with internal transitions. As mentioned in Chapter 3, "Transitions and Triggers," events work like interrupts. The conditional part of a compound trigger is only evaluated when the event part is generated.

Do Not Use Condition-Intensive Triggers

Even in compound triggers, you should avoid using condition intensiveness. Using condition-intensive triggers, especially with internal actions, is the mark of poor architecture, as these triggers are difficult to build and maintain, have low readability, and slow the performance of the system.
Any application can be built with a single mode, the root mode, and many internal transitions with actions. In the absence of modes, the triggers require many conditions to express the differences between the states of the system. This is highly discouraged. Figure 9-3 illustrates this.

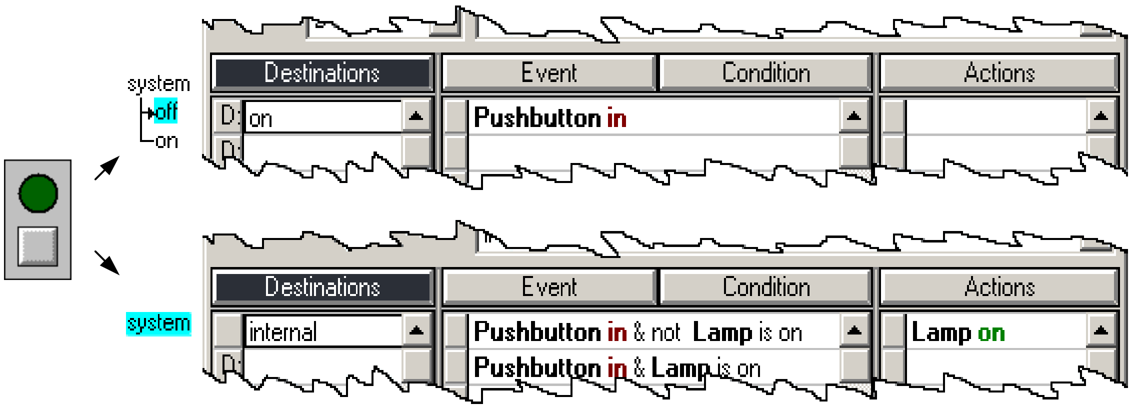


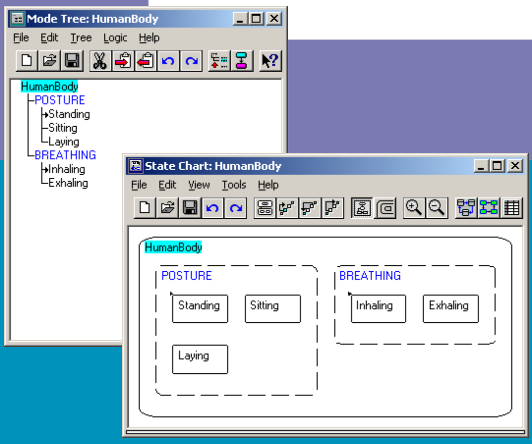
Figure 9-3: In the absence of modes, conditions express the difference in system state

Tip:
Use internal transitions with actions that cause a *quantitative* rather than a *qualitative* change in the system.

Exercise 9-2: Internal actions

Name: Television8
Description:
In this exercise you will add a clock to the television. The clock will be updated using a timer in an internal action.
Instructions:

1. Open the application Television7.rpd and save it as Television8.rpd.
2. Adapt the application to the following new requirement:
   - When in ***Standby***, the display should show the current system time.
   - For simulation purposes, assume that 12 seconds in real life equals 1 minute in the simulation.
3. Use a Time object to easily format the system's time for display. You can read about the functionality of a Time object in the RapidPLUS Online Help.
4. Use a timer object to advance the value of the time object.



Chapter 10

Modes Revisited: Concurrency

- Review of Modes
- Benefits of Concurrency

Review of Modes

The Mode Tree is the heart of any RapidPLUS application. A well-defined Mode Tree can simplify a lot of the development process. For this reason, it is worth reviewing the previous discussion of modes. For a more substantial review, you may want to return to Chapter 1, "Modes and the Mode Tree."

Types of Modes

Exclusive Modes

- Only one sibling is active at any given time.
- Each mode expresses mutually exclusive behaviors.

For example, a person cannot sit and stand at the same time.

Concurrent Modes

- All siblings are active at the same time.
- Each mode expresses independent subsystem of the whole.

For example, a person's stance and breathing are unrelated and thus concurrent.

The Mode Tree

A well-defined Mode Tree is descriptive:

- The modes represent the behaviors of the system.
- Modes are organized in a hierarchy; where higher-level modes denotes more abstract behaviors, and lower level modes express more concrete behaviors.
- The names chosen for the modes tell exactly what behavior the mode represents.

Benefits of Concurrency

Life Without Concurrency

Concurrency is a sort of abstraction. Any system can be defined with only exclusive modes, but other than the logic of separating independent subsystems with concurrency, there's also a very practical reason to do so.
For example, a typical human being has three basic postures: stand, sit, and lay down. Also, a human being has two modes of breathing: inhaling and exhaling.
To express all the possible modes a human being can be in, without using concurrency, you would end up with a list resembling this:

StandInhale	***SitInhale***	***LayDownInhale***
StandExhale	***SitExhale***	***LayDownExhale***

A human being can go from each of these modes to any other. This leads to a state chart that looks like this:

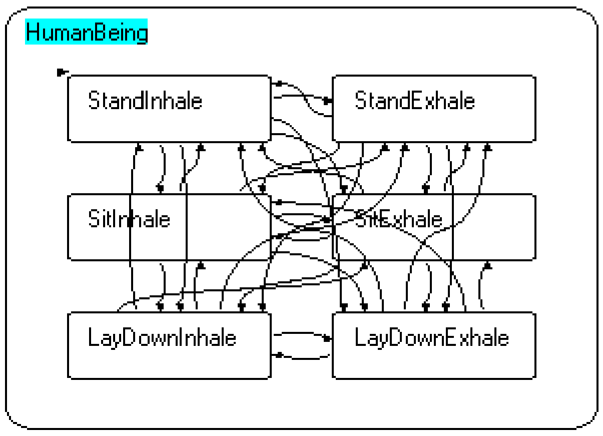


Figure 10-1: A mess of transitions, as shown in the RapidPLUS State Chart tool

You may consider using a junction transition, but even so, what if you decide that a human being can also crouch and hold his breath? This alone will add 6 more modes to the system, and if we don't go for a junction, another 102 transitions. In short: a headache to maintain.

Life With Concurrency

Our human being has two distinct and independent subsystems: posture and breathing. Because these subsystems are independent, they are concurrent to one another. Using concurrency to separate these subsystems results in a much clearer view on the human being:

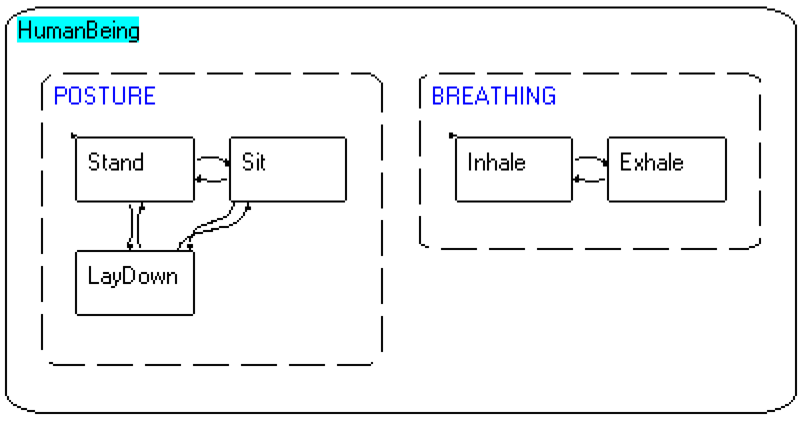


Figure 10-2: Much easier to understand

Some Math

Imagine a mode tree with 6 concurrent modes each having 10 exclusive children. In this case we have 66 modes: 6 concurrent modes plus 6 times 10 exclusive modes. Without concurrency we would have to express every different state of the system as an exclusive mode. In this case we would have 1 million modes: 10 exclusive modes per branch to the power of 6 branches.

Exercise 10-1: Concurrency

Name: Television9
Description:
In this exercise you will add the element of concurrency between two subsystems of the television.
Instructions:

1. Open Television8.rpd and save it as Television9.rpd.
2. Adapt the application to the following new requirements:
   - The sound can either be audible or muted.
   - Toggling between these functionalities is done by a new pushbutton: the Mute pushbutton.
   - When muted, a blue indicator lamp should be lit.

Question 10-1:

In Exercise 10-1, where was the concurrency placed in the mode tree?

Chapter 11

Data Objects

- Introduction to Data Objects
- Integer
- String
- Array
- Data Store
- Array of Objects

Introduction to Data Objects

Data Objects

Systems usually hold data. For example, a mobile phone may hold a list of names with phone numbers, the score of a game the user is playing, and other variable information. Table 11-1 lists the native RapidPLUS data objects, along with their icons in the Object Palette.

Note:

To see the different data objects, click the Data Objects icon in the Object Palette.

Type	Description
String	Holds an ordered collection of characters.
Number	Holds a floating-point real number.
Integer	Holds a natural number.
Random Number	Generates a pseudo-random number of type Number.
Holder	Pointer to other active objects.
Array	An array of active objects of the same type. Can have 1 to 7 dimensions.
Data Store	Holds a table of records made of various fields. A field can be of type String, Number, or Integer.
Point	Holds a pair of numbers of type Number.

Table 11-1: The data object types

Constant Data Objects

RapidPLUS also supports several constant data types, as shown in Table 11-2.

Note:

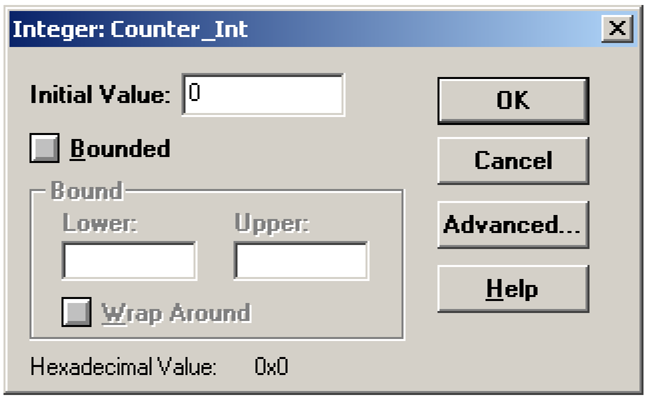
To see the different constant data objects, click the Constant Data Objects icon in the Object Palette.

Type	Description
Constant String	Holds a constant ordered collection of characters.
Constant Number	Holds a constant floating point real number.
Constant Integer	Holds a constant natural number.
Constant Array	Holds a constant array of active objects of the same type. Can have 1 to 7 dimensions.
Constant Set	A set of names, each describing an integer value.

Table 11-2: The constant data object types

Integer

To add an integer, click the Integer Object icon in the Object Palette. A dialog box opens and prompts you to enter the name of the new integer. Click the More button to open the Integer dialog box. In the Integer dialog box, you can set the Integer's initial value.


Integer: Counter_Int

Initial Value: 0

☐ Bounded

Bound

Lower:

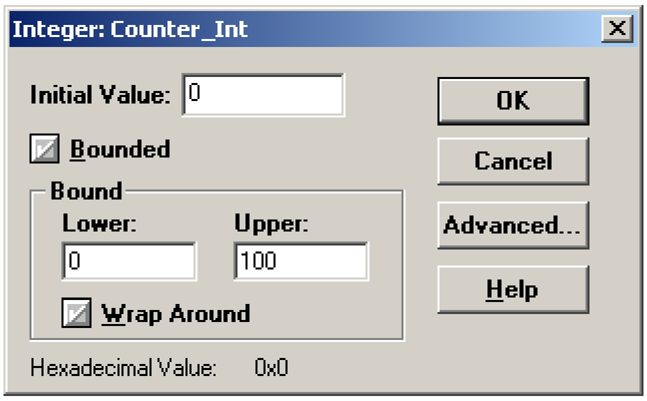
Upper:

☐ Wrap Around

Hexadecimal Value: 0x0

Figure 11-1: The Integer dialog box

An integer can be bounded by lower and upper limits, meaning its value will not exceed them. Set limits by selecting the Bounded option and filling in the lower and upper values.


Integer: Counter_Int

Initial Value: 0

☑ Bounded

Bound

Lower: 0

Upper: 100

☑ Wrap Around

Hexadecimal Value: 0x0

Figure 11-2: Wrap around integer

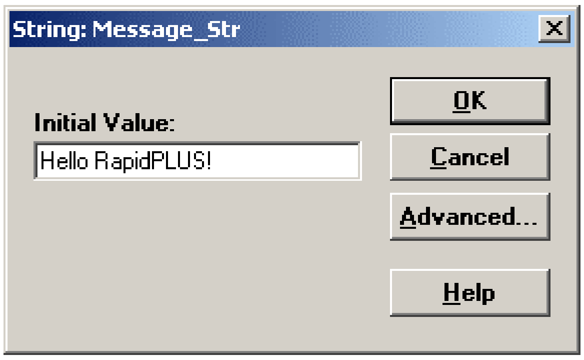
If you select the Wrap Around option, the integer value will wrap around the lower and upper limits, meaning that if the integer exceeds either limit, its value is set immediately to the other limit. For example, if the value of the integer shown in Figure 11-2 is 0 and it changes by -1, its new value will be 100.

Exercise 11-1: Integer
Name: Television10
Description:
In this exercise you will add to the television, the ability to cycle through the different channels.
Instructions:

1. Open Television9.rpd and save it as Television10.rpd.
2. Adapt the application to the following new requirements:
   - The television now has 31 channels ranging from 0 to 30.
   - Add two pushbuttons to the layout, and label them + and -.
   - When the television is in ***Standby*** mode, pushing the + or - buttons switches it to ***Operate*** mode on Channel 1.
   - When the television is in ***Operate*** mode, pressing the + or - buttons cycles through the channels.
   - In ***Operate*** mode, the display should show the current channel.

String

To add a string, click the String Object button in the Object Palette. A dialog box opens and prompts you to enter the name of the new string. Click the More button to open the String dialog box. In the String dialog box, you can set the string's initial value.


String: Message_Str

Initial Value: Hello RapidPLUS!

Figure 11-3: The String dialog box

When a string is used in an arithmetic operation, RapidPLUS automatically converts it into a numeric value, according to the numeric characters it contains prior to any non-numeric ones. For example, the String “123Go!” will be converted to the number 123, while the String “R2D2” will be converted to 0.

String Manipulation

For the purpose of the following sections, assume that the value of Message_Str, which is a string object, is “Hello RapidPLUS!”.

Extracting Substrings

There are three ways to extract substrings from a given string:

- To extract the substring that begins at a specific index, use the *stringFrom* function. For example:

  Extracted_Str := **Message_Str stringFrom: 12**

  In this case, the value of Extracted_Str will be “PLUS!”.

- To extract the substring that ends at a specific index, use the *stringTo* function. For example:

  Extracted_Str := **Message_Str stringTo: 5**

  In this case, the value of Extracted_Str will be “Hello”.

- To extract the substring that starts and ends at specific indexes, use the *stringFrom: To:* function. For example:

  Extracted_Str := **Message_Str stringFrom: 7 To: 11**

  In this case, the value of Extracted_Str will be “Rapid”.

Altering Strings

Two useful ways of altering strings are padding strings and replacing substrings:

- To pad the string with spaces to the left or right use *padSpacesLeftTo* and *padSpacesRightTo* respectively. For example:

  Padded_Str := **Message_Str padSpacesLeftTo: 20**

  In this case the value of Padded_Str will be “   Hello RapidPLUS!”.

- To replace a substring in a specific string with another one, use the *replaced: By* function. For example:

  Replaced_Str := **Message_Str replaced: 'RapidPLUS' By: 'World'**

  In this case, the value of Replaced_Str will be “Hello World!”.

Searching a String

You can search a string for a specific substring by using the *searchFor* function. The function will return the index of the first instance of the substring in the string. If no instance was found, the function will return 0. For example:

FoundIndex_Int := **Message_Str searchFor: 'Rap'**

In this case, the value of FoundIndex_Int will be 7.

Exercise 11-2: String

Name: EnjoySnack
Description:
In this exercise you will practice different string manipulation functions.
Instructions:

1. Start a new application and save it as EnjoySnack.rpd.
2. Develop the application to meet the following requirements:
   - The system has a 6-character text display, and a 3-station rotary switch, with stations named Slow, Medium, and Fast.
   - Initially the display is clear, and the switch is set to Slow.
   - The display shows a scrolling message: “Enjoy a snack”.
   - The message scrolls from left to right, repeatedly, at the speed set by the switch.

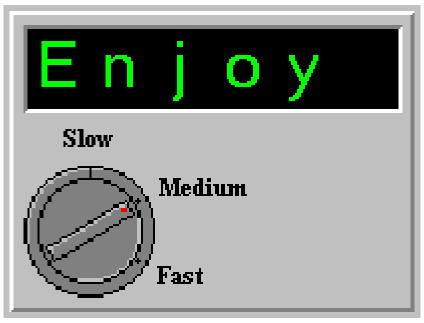


Figure 11-4: The EnjoySnack system

Array

An array holds data of a single type: integer, number, string, or object. Arrays of objects will be discussed later in this chapter. The data is stored in 1 to 7 dimensions and can be accessed by stating the name of the array followed by an index to each dimension, separated by a comma and bounded by square brackets. The indexes to the dimensions are based at 1. Accessing the cell at the second column of the fifth row would look like:

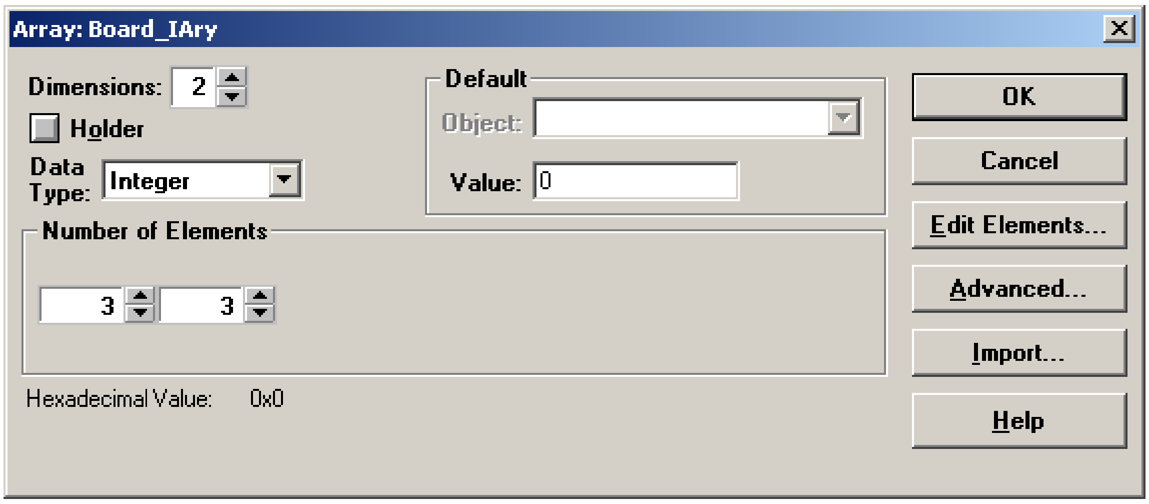
Map_IAry[5, 2] := **1**

You can save and load arrays from files by using the *saveToFile* and *loadFromFile* functions of the array. The file extension is RAR.

Using Arrays

Creating an Array

To add an array, click the Array Object icon in the Object Palette. A dialog box opens and prompts you to enter the name of the new array. Click the More button to open the Array dialog box.


Array: Board_IAry

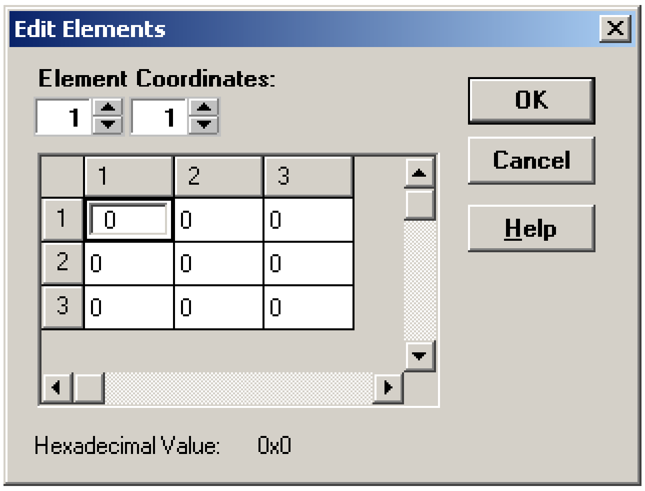
Dimensions: 2
Holder
Data Type: Integer
Number of Elements
3 3
Hexadecimal Value: 0x0
Default
Object:
Value: 0

Figure 11-5: The Array dialog box

In the Array dialog box you can set up the number of dimensions, the number of elements in each dimension, the type of stored data, and a default value for all elements stored in the array.

Editing the Elements in the Array

Click the Edit Elements button to open the Edit Elements dialog box.



	1	2	3
1	0	0	0
2	0	0	0
3	0	0	0

Figure 11-6: Editing the elements of an array

You can use the Element Coordinates selectors to toggle between different elements as you edit the contents of the array.

Tip:
You can use Ctrl+Arrows to navigate easily between the elements of the array.

Exercise 11-3: Array
Name: ArrayStepper
Description:
In this exercise you will develop an application that shows the contents of an array's cells.
Instructions:

1. Start a new application and save it as ArrayStepper.rpd.
2. Develop the application to meet the following requirements:
   - The system has a one-character text display and two stepper switches with three stations ranging from 1 to 3.
   - Create a 3 by 3 array and fill it with capital letters from A to I.
   - The stepper switches represent the indexes into the array.
   - The display always shows the character stored in the array at the indexes represented by the stepper switches

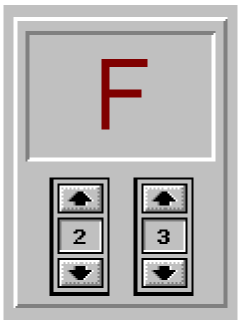


Figure 11-7: The ArrayStepper system

Data Store

Data Store objects are used to store tables of records, where each record contains several fields of data. A record is represented as a row in the table, while each field is stored in a different column. You can store number, integer, and string data in a data store object. For example, a data store can be used to store a phone book for a mobile phone. In this case, you would have the following fields: First name, Last name, Phone number, and Address.
You access the stored data by using the name of the object followed by the index of the required row of data. The index can either be an integer or a unique name you give the row when creating the object. For example:

Cashflow_Ds[4].*Income* := **100**
Cashflow_Ds['April'].*Income* := **100**

You can save and load data stores from files by using the *saveToFile* and *loadFromFile* functions of the data store. The file extension is RDS.
For more information about the Data Store object, please refer to the *RapidPLUS User Manual.*

Exercise 11-4: Data
Name: SimpleEditor1
Description:
In this exercise you will practice the use of data objects.
Instructions:

1. Start a new application and save it as SimpleEditor1.rpd.
2. Develop the application to meet the following requirements:
   - The system is a simple string editor.
   - The system has a 10-character text display and four pushbuttons, marked: 1, 2, 3, and Clr.
   - Pressing one of the numeric pushbuttons appends the corresponding digit to the end of the edited string.

- The string may reach a length of 20 digits but only the last 10 digits in it are shown on the display.
- Trying to add a digit when the string is full causes the system to beep (3000Hz, 400ms).
- Pressing the Clr pushbutton for less than 500 ms deletes the last digit in the string.
- Holding the Clr pushbutton for more than 500 ms causes the entire string to be deleted.

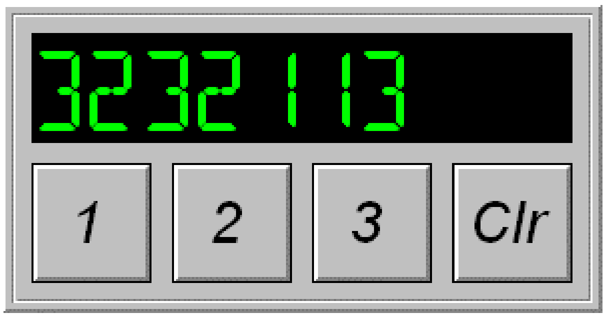


Figure 11-8: The SimpleEditor1 system

Array of Objects

An array of objects is a special kind of array that contains a specified type of graphic object, such as a set of pushbuttons.
The array lets you carry out identical logic on a series of different objects of the same type by referring to array indexes rather than to specific objects. It can also generate copies of existing objects and delete generated object, at runtime. Newly added objects are hidden by default. For example, adding new elements to an array would look like:

KeyPad_PbAry addMore: 1 copiesOf: Key_Pb

The array has the same set of events as the objects it holds. For example, an array of pushbuttons can generate the *in* event. The event is generated for the array when any one of the pushbuttons in it is pushed in. In order to know which element in the array generated the event, you call the *lastEventIndex* function of the array:

KeyPad_PbAry lastEventIndex

Exercise 11-5: Array of objects

Name: SimpleEditor2

Description:

In this exercise you will enhance the simple editor application by adding 7 more pushbuttons to complete the set of decimal digits. You will use an array of objects to handle the pushbuttons.

Instructions:

1. Open SimpleEditor1.rpd and save it as SimpleEditor2.rpd.
2. Adapt the application to these new requirements:
   - The keypad now has seven more pushbuttons: 4 through 9 and 0.
   - Minimize the number of activities and actions.
3. Use a constant string as a reference for the digit to add to the edited string.

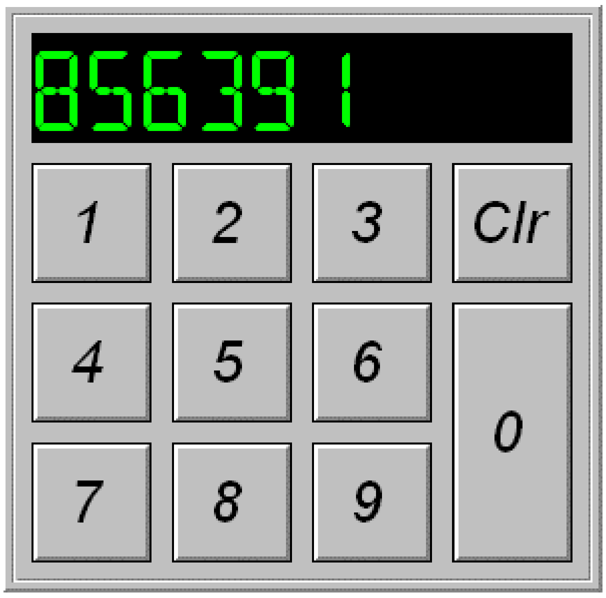
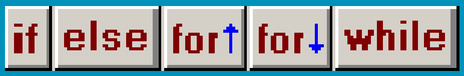


Figure 11-9: The SimpleEditor2 system

Chapter 12



Local Variables, If Branches, and Loops

- Local Variables
- If Branches
- For Loops
- While Loops

Local Variables

RapidPLUS supports local variables of two types: number and integer. You declare a local variable by using the *declare* keyword in combination with the variable's type and name, within angle brackets, and separated by a colon. For example:

declare <Integer: i>

Tip:
You can easily add declarations of local variables from the Logic Editor's Logic menu. Select "Declare local variables," and then the variable's type.

The local variable is only declared for the block of activities directly beneath the *declare* statement. This block of activities is indented to clarify the scope of the declared variable. The *declare* statement is the header of that block of activities.

Indentation Explained

Each line in a block is indented under the header of the block. If you create the header first, RapidPLUS will automatically indent the new lines created under it.
When a line is indented:

- The edit line contains a right angle bracket (>) for each indent.
- The Line Selector for each line in the block contains a right angle bracket for each indent and the text is indented accordingly.

You can change the indentation of a specific line by adding or removing the right angle brackets at its beginning when editing the line, or by right-clicking the line and selecting Increase indent or Decrease indent. Note that changing indentation can only be performed when the result is a valid block of logic.

If Branches

If branches are used to execute blocks of activities that are dependent on one or more conditions being true. RapidPLUS supports If branches, If...else branches, and nested branches.
If branches can be used in entry activities, exit activities, actions, and user-defined activity functions. For information on user-defined activity functions, please refer to Chapter 13, "User-Defined Functions."

Defining an If Branch

1. In the Logic Palette, click the If button. This will append the following logic to the Logic Editor's edit line:

   if <Condition>

2. Enter the condition.
3. Press the Enter key to accept the If branch header. The next line in the Logic Editor is automatically indented.
4. Add activity lines to the If branch block. The lines in the block are equally indented.
5. To close the block, press the Enter key twice after entering the last activity.

Tip:
Instead of clicking the If button you can simply type the keyword "if" in the edit line.

Defining an If...Else Branch

1. Follow steps 1 to 4 of "Defining an If branch".
2. In the Logic Palette, click the Else button. This will append the keyword "else" to the Logic Editor's edit line. The line indentation will decrease automatically.
3. Press the Enter key to accept. The next line in the Logic editor is automatically indented.
4. Add activity lines to the Else block. The lines in the block are equally indented.
5. To close the block, press the Enter key twice after entering the last activity.

Tip:
Instead of clicking the Else button, you can simply type the keyword "else" in the edit line.

For additional information on how to use if branches, please refer to the *RapidPLUS User Manual Supplement*.

For Loops

For loops are used to execute a block of activities, repeatedly, a known number of times. A For loop consists of a header and a block of activities. The header contains the keyword "for" and a definition of how many times the loop will be executed.
For loops can be used in entry activities, exit activities, actions, and user-defined activity functions.

There are two types of For loops in RapidPLUS: increasing loops and decreasing loops, as shown in the following sample headers.
Increasing:

for <Integer:counter> from src to dst step stp

Decreasing:

for <Integer:counter> from src downTo dst step stp

In both types of loops:

- "counter" is an integer variable, serving as the loop counter. It is also available as a local variable within the activities block of the For loop.
- "src" is an integer value, serving as the starting value of the loop counter.
- "dst" is an integer value, serving as the ending value of the loop counter.
- "stp" is a positive integer value. In an increasing loop it is added to the loop counter at the end of each cycle, and in a decreasing loop it is reduced from the loop counter.

The loop terminates when "counter" becomes greater than "dst" for increasing For loops or less than "dst" for decreasing For loops.

Note:
src, dst, and stp can all be expressions resulting in integer values. If so, they will be re-evaluated at the beginning of every loop cycle.

Defining a For Loop

for↑ for↓

1. In the Logic Palette, click the appropriate For button, depending on whether the loop counter should increase or decrease. This will append the following logic to the Logic Editor's edit line:

   for <Integer:i> from <Integer> to <Integer> step 1

   or:

   for <Integer:i> from <Integer> downTo <Integer> step 1

   depending on which button you click.
2. You can rename the counter. Set the start and end values, and if necessary, change the step value.
3. Press the Enter key to accept the For loop header. The next line in the Logic Editor is automatically indented.
4. Add activity lines to the For loop block. The lines in the block are equally indented.
5. To close the block, press the Enter key twice after entering the last activity.

Tip:
Instead of clicking the For buttons, you can simply type the keyword "for" and the rest of the header keywords, "from", "to" or "downTo", and "step", in the edit line.

For additional information on how to use for loops, please refer to the *RapidPLUS User Manual Supplement*.

While Loops

While loops are used to execute a block of activities, repeatedly, as long as one or more conditions are true. A While loop consists of a header and a block of activities. The header contains the keyword "while" and a condition or a set of conditions with logical relations between them.
While loops can be used in entry activities, exit activities, actions, and user-defined activity functions.

Defining While Loops

1. In the Logic Palette, click on the While button. This will append the following logic to the Logic Editor's edit line:

   while <Condition>

2. Enter the condition.
3. Press the Enter key to accept the While loop header. The next line in the Logic editor is automatically indented.
4. Add activity lines to the While loop block. The lines in the block are equally indented.
5. To close the block, press the Enter key twice after entering the last activity.

Tip:
Instead of clicking the While button, you can simply type the keyword "while" in the edit line.

For additional information on how to use While loops, please refer to the *RapidPLUS User Manual Supplement*.

Important:
RapidPLUS executes all the cycles of a loop, either For or While, in the same state machine cycle. This is important to remember because this means that as long as a loop is executed, no transitions and no changes to the objects' status are made. Only the activities of the block in the loop are performed.

Day 2 Summary

- Day 2 Recap
- Review Questions

Day 2 Recap

Chapter 7 presented an exercise on state modeling. This is a very important skill as it is used every time we start development of a new application. You should continue exercising this skill. Try modeling a state transition diagram of a well known home appliance.
Chapter 8 provided information and methodology for one of the most used RapidPLUS objects: the timer object. The chapter presented the different functions provided by the RapidPLUS timer object and discussed two methods for timer reuse: dedicated and general-use timers.
Chapter 9 covered transition actions and internal actions. Transition actions are used in order to create route-specific instead of mode-specific logic. Internal actions are used to handle triggered activities while the mode is active.
Chapter 10 revisited modes, in a discussion on the benefits of using concurrency.
Chapter 11 presented several of the RapidPLUS objects dedicated to holding data. It covered integers, strings, arrays of data and of objects, and the Data Store object.
Chapter 12 covered the topics of defining local variables, using If and If...else branches, and the use of For and While loops.

Review Questions

1. Explain in your own words the difference between dedicated and global-use timers.
2. When should transition actions be used instead of entry activities?
3. When should exit activities be used instead of transition actions?
4. When should internal actions be used and what alternatives do we have?
5. What is the execution order of these activities?

Number:
Outgoing call number:
SIM: Ready
PIN code: 1234
PUK code: 12345678
Operator long name: Orange BU
Operator short name: ORANGE
Operator number: 42501
Network ID: 1
SIM state: PIN2

Day 3

Introduction to User-Defined Objects

Chapter 13

User Functions

- User Functions
- Creating and Editing Functions
- Working with User Functions

User Functions

What is a User Function?

A user function is a block of RapidPLUS logic that can be invoked as a single function within an activity, an action, or a condition. User functions become available for use within the system as functions of the root object, *self*. They are useful when you need to repeat the same set of activities or use the same condition in several places in the application.

There are two types of user functions: activity functions and condition functions. The following is a short description of the two:

- **Activity function**—a function that performs activities. It can be used either in entry or exit activities, or as an action (either internal or transition based), but not as a mode activity.
- **Condition function**—a function that acts as a condition, and is used for that purpose. The name of the function includes the word "is" or the word "has" as a prefix, to emphasize the question being asked, e.g., *is initialized* may be the name of a condition function that evaluates to True if the system is initialized and to False if it is not.

User functions, like other RapidPLUS functions, can receive arguments. The arguments can be of any object type. This gives the functions flexibility as the arguments may refer to different objects (of the argument's type) on each function call so the function can be executed on different objects each time, and not just perform a predefined set of activities on one set of objects. We will discuss passing arguments to a user function later in this chapter.

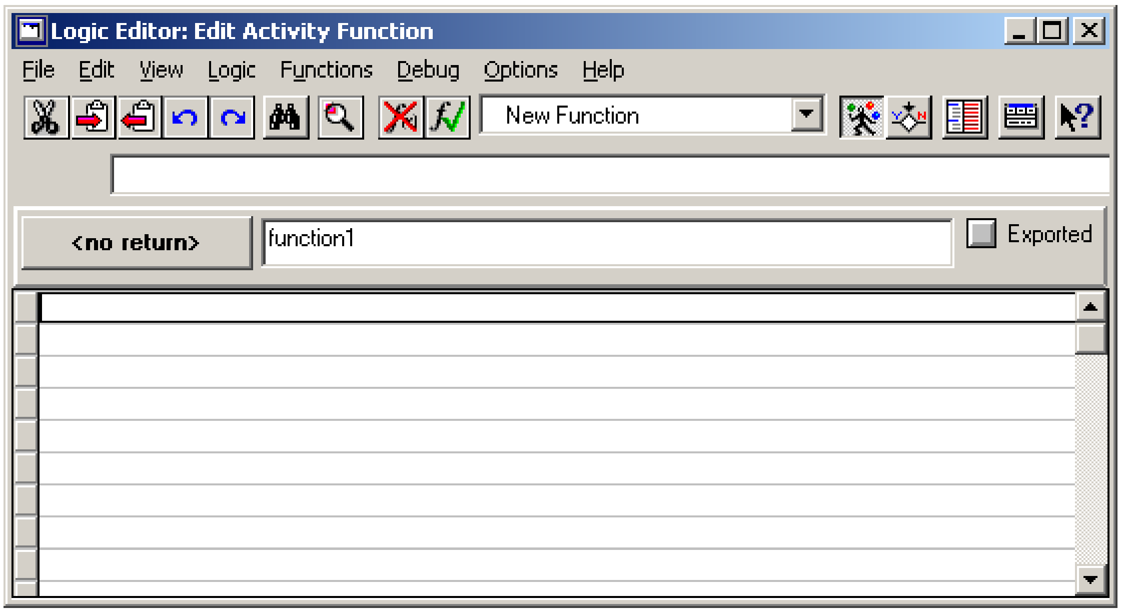
Creating and Editing Functions

The Function Editor Window

The Function Editor window is actually the Logic Editor window in function editing mode. To switch the view of the Logic Editor to the Function Editor, select User Function from the View menu of the Logic Editor. You can revert back to mode logic editing by selecting Mode Logic from the View menu.

Tip:

You can use the Edit User Function button in the Logic Editor window toolbar to bring the Function Editor into focus quickly. Once you do, the button will change to the Logic Editor button, which you can then use to revert back to mode logic editing.

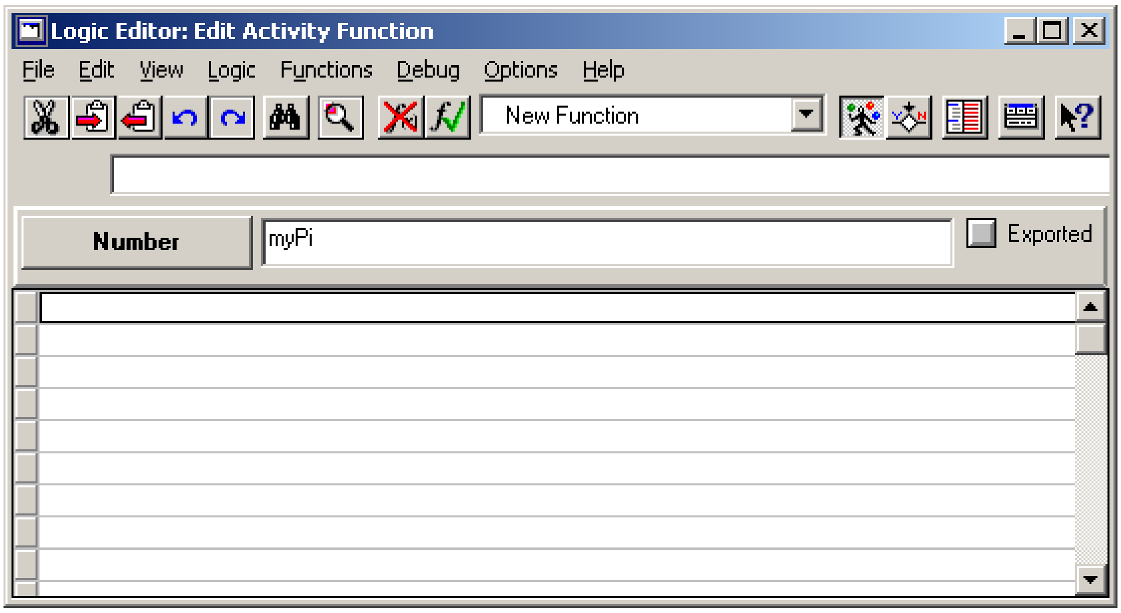

Logic Editor: Edit Activity Function
File Edit View Logic Functions Debug Options Help
New Function
<no return>
Exported

function1

Figure 13-1: The Function Editor window

Creating a New Activity Function

1. In the Function Editor window, select Activity Function from the Functions menu.
2. Select New Function from the user function list if it is not already selected.
3. Type a descriptive name in the Function box, replacing the default name. In this example, the function is called “myPi.”
4. Select the return value’s type, if your function should return a value of any sort. In this example, Number is the return type. Figure 13-2 illustrates this.


Logic Editor: Edit Activity Function
File Edit View Logic Functions Debug Options Help
New Function
Exported

Number

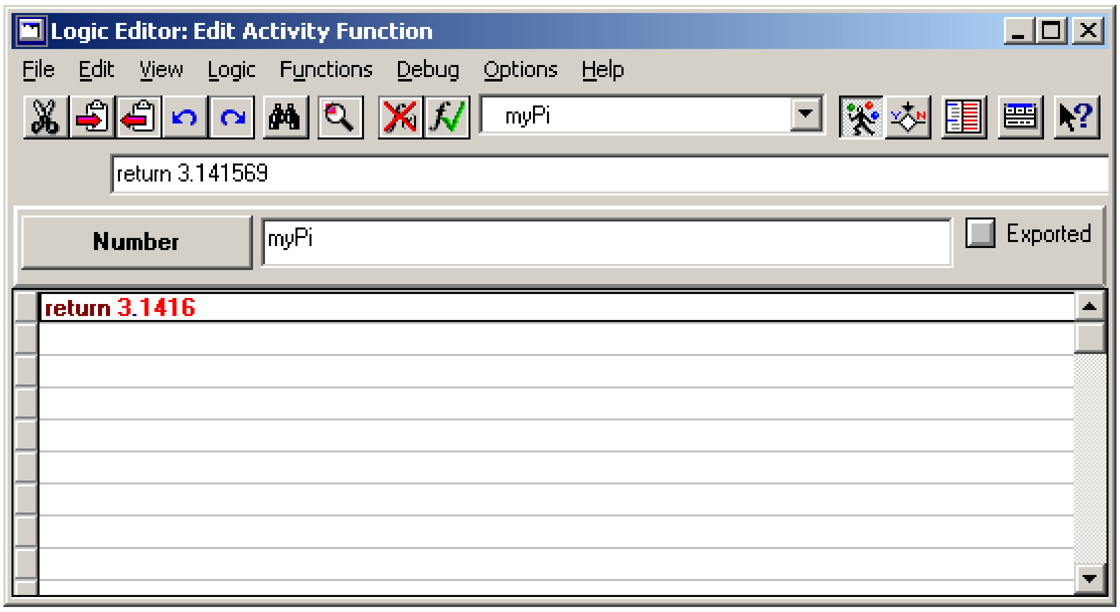
myPi

Figure 13-2: A new activity function with its name and return value type.

5. Write the function's logic in the empty lines at the bottom of the window. As this is an activity function, the logic is much like for the logic for activities and actions. You can use the Logic Palette to call specific activity functions of the objects in your layout, or even other activity functions.

   For the purpose of this example, the function returns the value of the mathematical symbol Pi (π). To do so, use the reserved word "return," along with a rough estimate of Pi.

6. Once done, select Accept Function from the Functions menu. Figure 13-3 shows the completed function.



```
return 3.141569
```

Name: myPi

```
return 3.1416
```

Figure 13-3: The completed myPi function

Tip:

You can use the Activity Function button in the Function Editor window toolbar to quickly switch to activity function editing mode.

Or you can use the Condition Function button to quickly switch to condition function editing mode.

You can use the Accept Function and Reject Last Changes buttons in the Function Editor window toolbar to accept the function or undo the changes done to it since last acceptance.

Creating a New Condition Function

The process of creating a new condition function is similar to the process of creating a new activity function. The difference is in the lines of logic. In a condition function, the lines of logic are conditions, separated by logic relations such as "or," "and," and "not." Instead of simply writing multiple conditions in the Condition column of the Logic Editor, you can create a function with multiple conditions on separate lines, with each line containing one condition.

Editing an Existing Function

Sometimes you need to edit existing functions, either for bug fixes or requirements changes. To do so:

1. In the Function Editor, select the function you wish to edit from the user function list. Note that you do not need to specify the type of function (activity or condition), as it is already defined for the function you wish to edit.
2. Once you have selected the function, its logic opens and you can edit it.

Functions That Receive Arguments

User functions can receive arguments and manipulate them. The arguments can be of any object type, whether RapidPLUS native objects or User-Defined Objects. We will discuss User-Defined Objects in Chapter 15, "The Makings of a User-Defined Object."

You define the arguments to be passed into the function in the function's name. This is referred to as the function's header. A pseudo header looks like:

FunctionName_arg1place: <argType1:arg1> arg2place: <argType2:arg2> ...

First is the function name, followed by a colon. Next the first argument is declared, in angle brackets. Any other arguments have a placeholder that becomes part of the function's name, followed by a colon, and then the argument's declaration within angle brackets. In the sample header,"arg1" and "arg2" are the names of the arguments passed into the function.

User functions and arguments naming rules and conventions

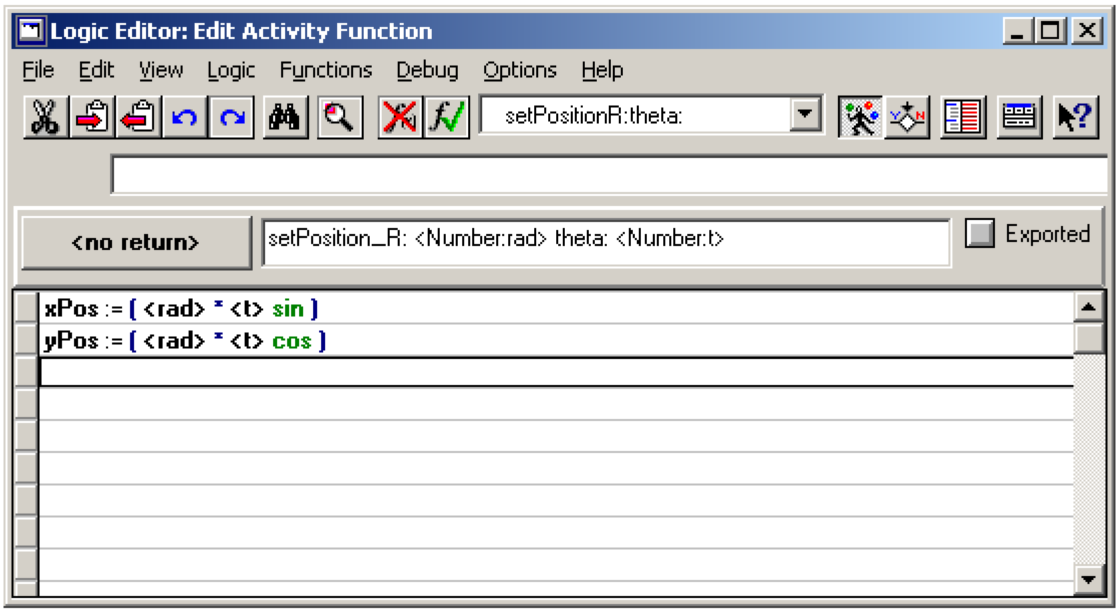
User functions names must obey the rules declared in the "Rules for naming user functions" section of the RapidPLUS online help documentation.

The following naming conventions are recommended:

- Capitalization should be used to separate adjacent words.
- The function name should include information regarding the first argument, if such is present.

Example of a User Function With Arguments

Figure 13-4 shows an example of a simple user function with two arguments that sets the position data objects, “xPos” and “yPos”, according to the radial coordinates “rad” and “t”.


Logic Editor: Edit Activity Function
File Edit View Logic Functions Debug Options Help
setPositionR:theta:
<no return>
Exported

setPosition_R: <Number:rad> theta: <Number:t>

```
xPos := [ <rad> * <t> sin ]
yPos := [ <rad> * <t> cos ]
```

Figure 13-4: A user function with two arguments

Working with User Functions

You work with user functions the same way you work with other RapidPLUS objects’ functions. User functions are functions of the root object *self*. To use the function, highlight self, and then double-click the function in the Logic Palette. Given the function *setPosition_R: theta:*, shown in Figure 13-4, usage may look like:

self setPosition_R: 5 theta: 35

In this case, “rad” receives the value 5, and “t” receives the value 35. The function sets the values of the data objects “xPos” and “yPos” accordingly.

Exercise 13-1: User Functions

Name: DecToBin

Description:

In this exercise you are going to develop a simple decimal to binary converter. In order to convert the decimal value to a binary representation, you will define and use a user function.

Instructions:

1. Start a new application and save is as DecToBin.rpd.
2. In the Object Layout, add the following objects to the application:
   - Four pushbuttons labeled 0, 1, 2, and 3.
   - An array of the buttons, ordered according to their labels.
   - A text display object.
3. In the Function Editor, develop a function that receives an integer as an argument and returns a string of 0s and 1s. The returned string is the binary representation of the received argument.
4. Add logic to the system to meet the following requirements:
   - The display initially shows 00.
   - When a pushbutton is pressed, the display changes to the binary representation of the number that was pressed.

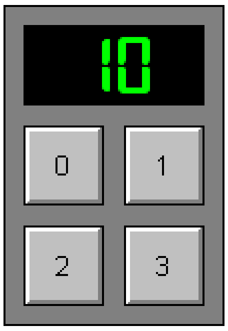
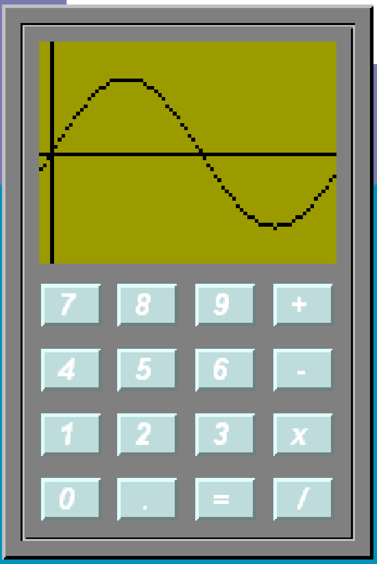


Figure 13-5: DecToBin running



Chapter 14

An Introduction to the GDO

- The Graphic Display Object
- Using the GDO

The Graphic Display Object

What is a Graphic Display Object?

Modern electronic devices use graphic displays to interact with the user in a more attractive fashion. Graphic displays offer visually rich man-machine interfaces and expand the abilities of modern devices. For example, the average modern mobile phone incorporates a complete graphical personal information management system, an integrated video camera, graphics-rich games, and even the ability to watch the news from your favorite television channel.

RapidPLUS Graphic Display Objects

RapidPLUS supports two such graphics displays through two special ready-made objects:

- **Graphic display object**—supports 2 to 256 palette colors.
- **Graphic display true color object**—supports 8 to 32 bit color depth.

Resolution

All graphic display objects are made up of a grid of points, called pixels. The number of pixels available on the display is called the display's resolution. The resolution is determined by the number of pixels in width, multiplied by the number of pixels in height. For example, the graphic display objects of RapidPLUS are set to 64x32 pixels by default. You can change this setting in the object's dialog box.

Note:
Throughout the rest of the book, Graphic Display Objects will be referred to by the abbreviation GDO.

Using the GDO

The following sections will outline basic usage of the GDO. For more detailed information on GDOs and their usage, refer to the *RapidPLUS User Manual Supplement*.

Setting Up a GDO

1. In the Object Palette, select the Display Objects group, and from it, select the Graphic Display True Color object.
2. Place the GDO in the layout. Its size is dependent on several settings, including its resolution. Figure 14-1 illustrates a newly created GDO in the layout.

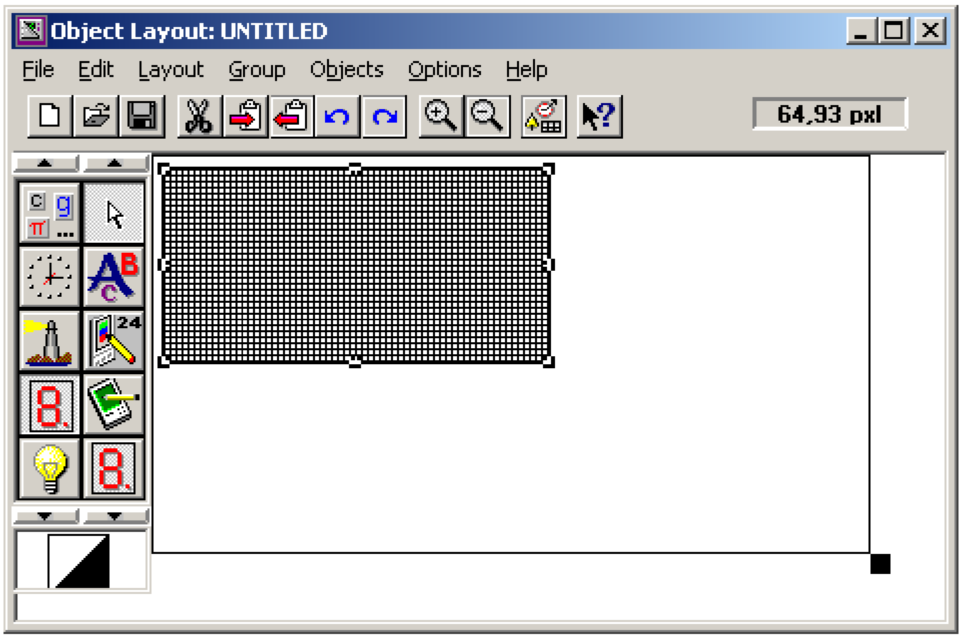
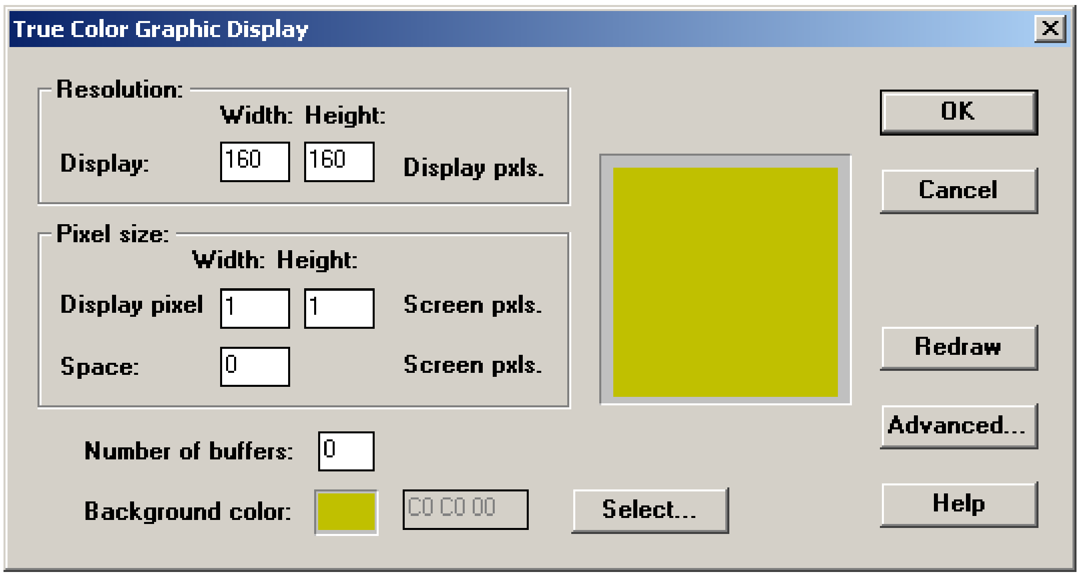


Figure 14-1: A newly created GDO.

3. Double-click the GDO and click the More... button to open the True Color Graphic Display dialog box.



Resolution:

	Width:	Height:	
Display:	160	160	Display pxls.

Pixel size:

	Width:	Height:	
Display pixel	1	1	Screen pxls.
Space:	0		Screen pxls.

Number of buffers: 0

Background color: C0 C0 00

Figure 14-2: Editing the GDO's properties

4. Adjust the resolution, the size of pixels in the simulation, the space between them, and other properties like the background color. Figure 14-2 shows the properties set for a 160x160 GDO with a background RGB color set to {192, 192, 0}.

5. When done, click OK.

6. Name your GDO in the Parameter Pane window and set its position. Note that changing its size will affect the settings of its resolution and pixel size. For the purpose of this example, the name of the GDO is Display_GDO.
7. When done, click Accept and close the Parameter Pane.

Drawing a Pixel

1. In the Logic Editor, select the mode in which you wish the activity to take place. For this example, we will use the entry activity of the root mode.
2. Select the GDO from the Logic Palette and append its *drawPixelAtx: y:* function to the logic.
3. Set the coordinates of the pixel to draw. For this example, the logic looks like:

Display_GDO drawPixelAtx: 10 y: 10

Exercise 14-1: Drawing pixels

Name: FuncExplore1
Description:
In this exercise you will draw sine and cosine waves on a GDO.
Instructions:

1. Start a new application and save it as FuncExplore1.rpd.
2. Build a system according to following requirements:
   - The system has a 160x160 pixel graphic display and a 3-stations rotary switch selecting between Off, Sin, and Cos.
   - When the switch is on Off, the display is clear.
   - When the switch is on Sin, the display shows a sine curve ranging from -4 to 4 on the X-axis and from -2 to 2 on the Y-axis.
   - When the switch is on Cos, the display shows a cosine curve in the same range.

Hints:

- Use the *clearDisplay* function of the GDO to clear the display when needed.
- RapidPLUS numeric objects have both *sin* and *cos* functions.

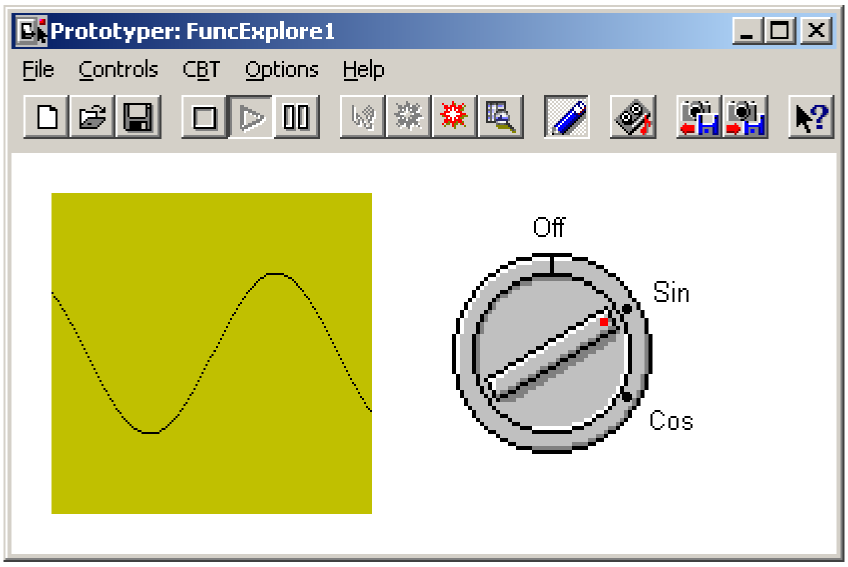


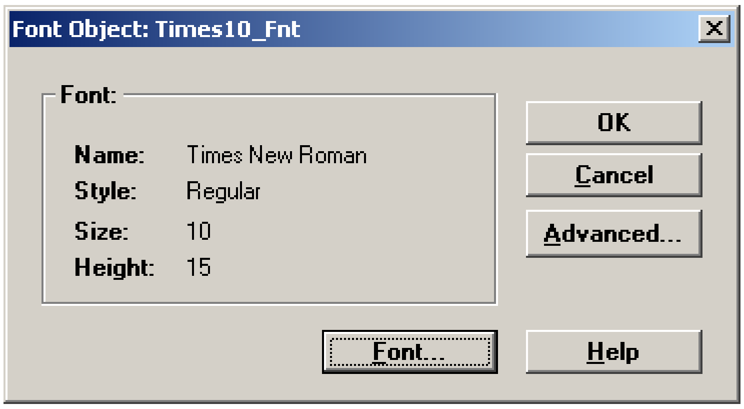
Figure 14-4: FuncExplore1 in action

Drawing Text on the GDO

The Font Object

Drawing text on the GDO requires that we work with a special object that represents a specific font. This object, the Font Object, lets you set the font that will be used, its typeface (referred to as font style), and its size.
In order to set up a font for use with a GDO:

1. Select the Font Object from the Display group. A dialog box will automatically appear asking you to name the new object. For the purpose of this example, name it Times10_Fnt, since you will use Times New Roman, size 10.
2. Click the More button to open the Font Object dialog box.



Name:	Times New Roman
Style:	Regular
Size:	10
Height:	15

Figure 14-5: Setting up the font

3. In the Font Object dialog box, click the Font button and select the appropriate font, style, and size. You can also select the language script to use. For this

example we select Times New Roman as the font, Regular as the style and 10 as the size.

4. When you are done, click OK repeatedly to close the Font dialog box, the Font Object dialog box, and the Parameter Pane.

Using the Font Object

In order to draw text on the GDO, the GDO needs to be set to use a specific Font Object. To do so:

1. In the Logic Editor, select the mode in which you want the GDO to use a specific font, and then select the appropriate activity type. In this example we will use an entry activity of the root mode.
2. From the Logic Palette, select the GDO's *fontSet:* function and append it to the logic.
3. Select the font object and append its name to the logic. The line of logic looks like:

Display_GDO fontSet: Times10_Fnt

Drawing the Text

Now that the GDO is set to use a specific font, you can start drawing text. You will need to specify the string to display and its position on the GDO. The position is the top-left corner of the string.

1. In a new line of logic, select the GDO's *drawText: atx: y:* function and append it to the logic.
2. Fill in the string to display, its x coordinate, and its y coordinate. For the purpose of this example, write the words "Hello GDO" at position 0, 0 (top-left corner of the GDO). The line of logic looks like:

Display_GDO drawText: 'Hello GDO' atx: 0 y: 0

Exercise 14-1: Drawing text

Name: FuncExplore2

Description:

In this exercise you will add the X-axis and Y-axis and a label for the graph to the display.

Instructions:

1. Open FuncExplore1.rpd and save it as FuncExplore2.rpd.
2. Adapt the application to meet this new requirement:
   - When displaying a graph, the GDO should also draw the x axis and the y axis, along with coordinates.
   - The top-left corner of the GDO should display "Sine" and "Cosine," according to the current mode.

Hint:

- Use the *drawTransparentText: atx: y:* function of the GDO to draw the text in this exercise. This causes the text to be drawn without the background.

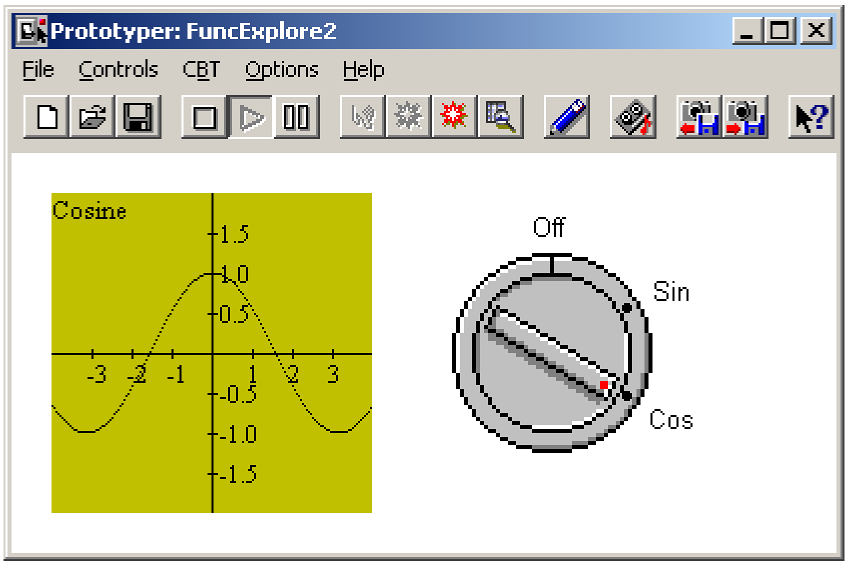
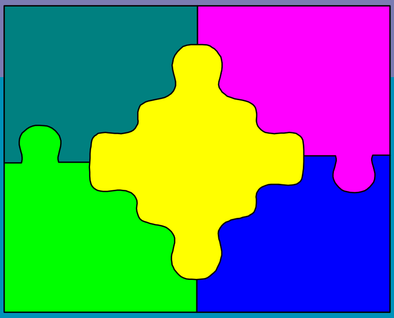


Figure 14-6: FuncExplore2 in action.



Chapter 15

The Makings of a User-Defined Object

- User-Defined Objects
- The Logic Interface of a UDO

User-Defined Objects

What is a User-Defined Object?

RapidPLUS applications can be very complex. Often, parts of the application act as discrete units, interacting with other parts of the application via a small set of functions and data elements.
As a project gets larger and more detailed, it becomes practically impossible for just one developer to implement and maintain. This means that group development is common in large RapidPLUS projects. Each member of the group develops one or more parts of the application.
After working on several RapidPLUS projects, you may notice that more than one project had the same set of functions and data elements serving the same purpose. For example, a set of objects, modes, functions, and data objects representing a battery may appear in several different applications, such as a camera, a mobile phone, and a remote control.
The previous paragraphs describe three characteristics of any modern software development project:

- Discrete units of functionality.
- Group development support.
- Reusable elements of logic.

RapidPLUS provides these in the form of the *User-Defined Object* (UDO).
A UDO is a discrete unit of functionality, developed by one of several developers in a group. It can be used in different applications. In fact, a UDO is a complete lower-level RapidPLUS application, being used by a higher-level RapidPLUS application. The higher-level application, the one using the UDO, is called a *parent application*.
Within the parent application, the UDO behaves much like native RapidPLUS objects. It provides functions, properties, and events that can be used in the parent application, and it can send messages to and receive messages from the parent application.
You build a UDO much like you build any other RapidPLUS application. You add objects, modes, transitions, triggers, and activities. Then you add special functions, properties, events, and messages that the parent application will use for interfacing with the UDO. When you are finished, you simply save the application as a UDO. Then you can add the UDO as one complete unit to the parent application, much like you add native RapidPLUS objects.

The Benefits of Using UDOs

When a development team uses UDOs, developers only need to concern themselves with the implementation of their own UDOs. They do not need to know the implementation details of other developers' UDOs, but only to be familiar with those UDOs' interfaces.
UDOs can be reused in different applications, thus expanding the RapidPLUS objects library with customized objects.
You can create nongraphic UDOs that contain only data and are used for logical operations only. For example, you could have a UDO that represents a phone record.

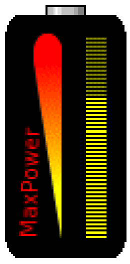
Finally, UDOs provide modularity even at the UDO level, since one UDO can be constructed from several other lower-level UDOs.

Exercise 15-1: Preliminary exercise

Name: Battery

Description:

In this exercise you are going to develop a simulation of a simple battery. The battery can be either ***Connected*** or ***Disconnected*** from an electric circuit. Once it is connected, it starts to provide power, thus lowering its own power level. As long as it has power, it is considered ***Alive***. Once it is drained, it becomes ***Dead***.



This simulation is a standalone RapidPLUS application, not a UDO.

Instructions:

1. Start a new application and save it as Battery.rpd.
2. Build the simulation according to the following specifications:
   - The battery is represented by two primitive frames. You can edit these frames in the Object Editor to improve their look.
   - The battery has a vertical-bar indicator object, showing how much power the battery has left. The properties of the indicator should be:
     - Value range: 0 – 100
     - Resolution: 2
     - Initial value: 100
     - Type: Column
     - Line color: transparent
   - When disconnected, the battery does not lose power.
   - When connected, the battery loses a unit of power every 150ms. This means its lifetime, when connected, is 15 seconds.
3. Develop an appropriate mode tree, add the objects you need, and define the transitions, triggers, and activities needed to simulate a battery.
4. In order to test the battery, add a switch that is responsible for connecting and disconnecting the battery from the electric circuit.

The Logic Interface of a UDO

A UDO needs to communicate with the parent application. It does so by means of functions, events, properties, and messages. These types of communication comprise the UDO's logic interface. Figure 15-1 illustrates the logic interface, along with the direction of communication.

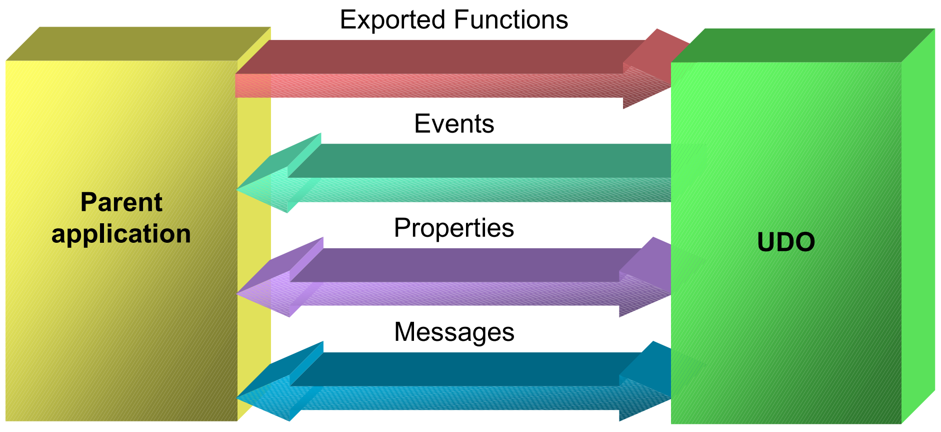


Figure 15-1: The logic interface of a UDO

As shown in Figure 15-1, the parent application can invoke the UDO's exported functions, receives events from the UDO, can set and get the values of the UDO's properties, and can exchange messages with the UDO.

Event Objects

Before we start going through the four types of communication between the parent application and the UDO, we need to familiarize ourselves with a special type of object: the Event object.

Note:
This topic is not coupled specifically with the logic interface of UDOs, as Event objects can be used with no relation to UDOs. The reason we go through them here is that they are used quite a lot with UDOs.

What Are Event Objects?

Event objects are a special kind of object that you can add to your application to simplify the logic in complex designs. For example, consider a system with two concurrent branches in which an activity in a child mode in one branch causes a transition between two child modes in the other branch. In this case you would need that activity to generate an event, which can be used in the other branch to trigger the transition.

RapidPLUS provides the solution in the form of an Event object. When you need to generate an event, you can simply use the *trigger* function of the Event object. This will generate the event. In RapidPLUS syntax the logic looks like:

myEventObject_Ev trigger

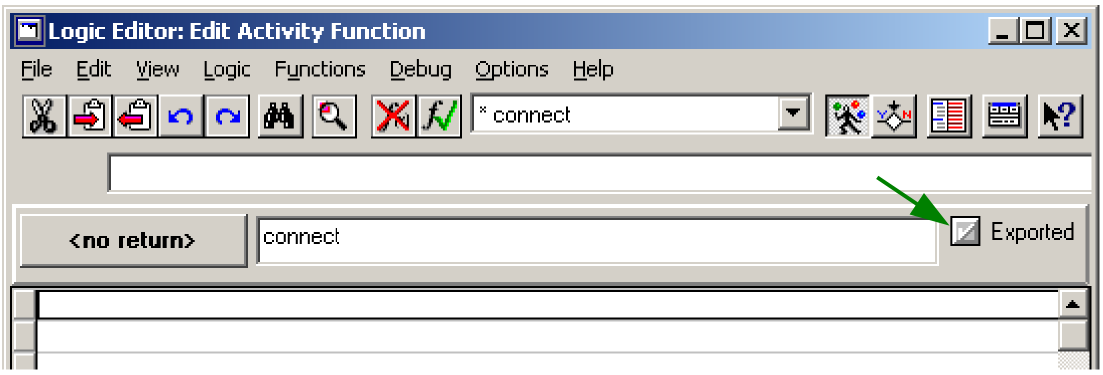
Event Object Usage Methodology

The following points outline two methods for using Event objects:

- Event objects can be used in concurrent branches to allow one branch to control transitions within a sibling branch by generating events that trigger the transitions.
- Event objects can also be used to combine compound triggers that are used in several places in the application. You can use an internal action with such a trigger at a parent level, to generate one event. Since there is now a single trigger—the event object—readability of the code increases. The price of using this method is that instead of executing the transition immediately, you generate an event that is only handled on the next cycle.

Exported Functions

RapidPLUS objects provide functions through which they can be manipulated. UDOs act the same, providing this ability through exported functions.
Exported functions are actually user functions that you define as exported. When you create a UDO, its exported functions are the only functions available from outside it. Figures 15-2 shows how to export a function in the Function Editor. Notice the asterisk that appears next to the name of the exported function.


Logic Editor: Edit Activity Function
File Edit View Logic Functions Debug Options Help

* connect

<no return> connect

Exported

Figure 15-2: An exported function being created

Exercise 15-2: Exported functions

Name: Battery

Description:

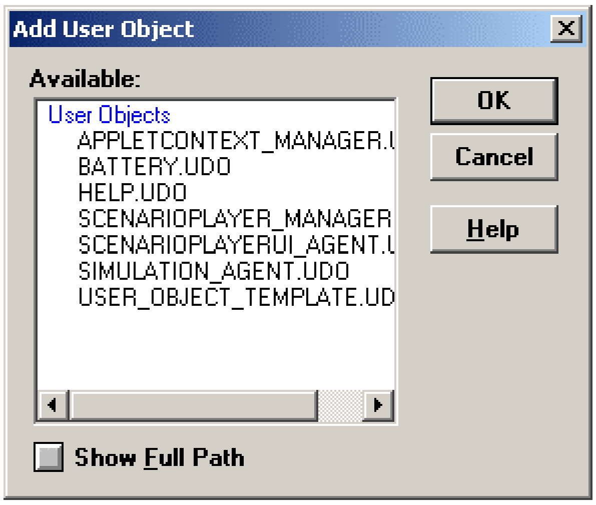
In this exercise, you are going to start converting the battery simulation from a standalone simulation to a fully featured UDO of a battery that will serve a parent application simulating an electric circuit. You will add two functions to the battery for connecting and disconnecting it.

Instructions:

1. Open Battery.rpd and save it as Battery.udo using the “Save As User Object” command from the File menu of the Application Manager window. This will save the battery as a UDO.
2. Add two Event objects to the layout and name them *Connect_Ev* and *Disconnect_Ev*.
3. Change the triggers for the transitions between the modes representing the battery being disconnected and connected. You will now use the Event objects you added instead of the switch.
4. Remove the switch object from the layout.
5. Add two exported user functions for connecting and disconnecting the battery. The only activity that each function should perform is triggering the appropriate Event object.

Adding a UDO to an Application

To add a UDO to an application, select Add User Object from the Objects menu of the Object Layout window. RapidPLUS scans predefined directories, along with the current working directory, for UDOs. When done, a dialog box appears that lets you select the UDO you want to use. Figure 15-3 shows the Add User Object dialog box.


Add User Object

Available:

User Objects
APPLETCONTEXT_MANAGER.U
BATTERY.UDO
HELP.UDO
SCENARIOPLAYER_MANAGER
SCENARIOPLAYERUI_AGENT.U
SIMULATION_AGENT.UDO
USER_OBJECT_TEMPLATE.UD

Figure 15-3: The Add User Object dialog box

After you select the appropriate UDO, you need to place it in the layout. A dotted blue frame surrounds graphic UDOs, as shown in Figure 15-4.

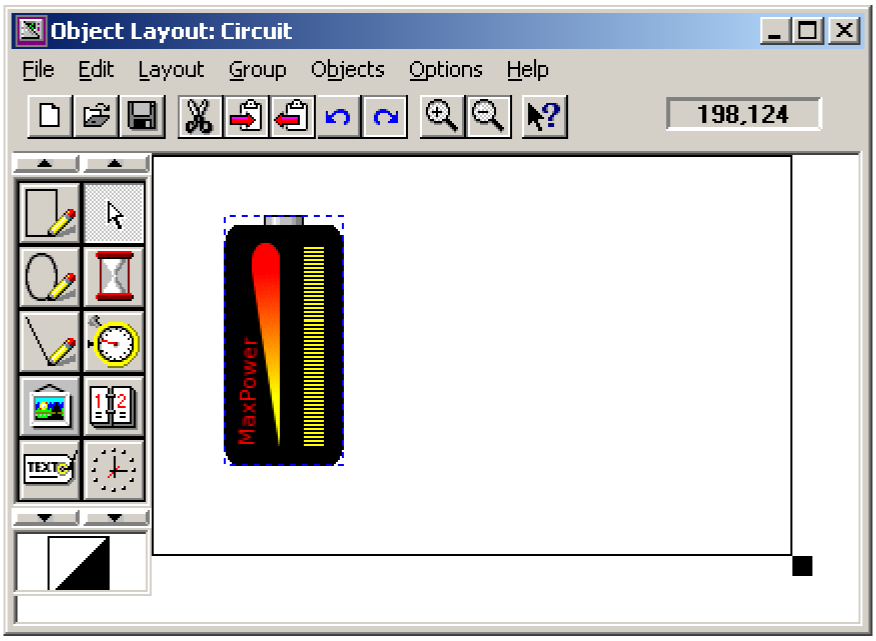
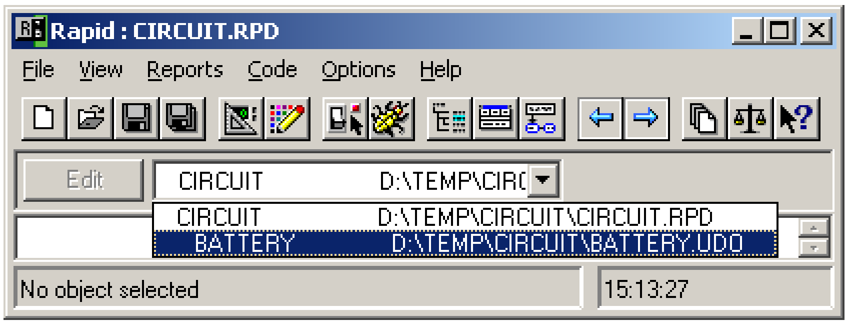


Figure 15-4: A dotted blue line surrounding a graphic UDO

You cannot edit the UDO directly from within the application; however, you can switch to the UDO without opening the file directly.
To do so, expand the Project Components list in the Application Manager window. This list includes all the UDOs in the application. UDOs are indented under the Parent Application. Nested UDOs are indented another level. Select the UDO you want to switch to from the list. Figure 15-5 shows the drop down list from the Circuit application.



```
CIRCUIT            D:\TEMP\CIRC
CIRCUIT            D:\TEMP\CIRCUIT\CIRCUIT.RPD
  BATTERY            D:\TEMP\CIRCUIT\BATTERY.UDO
No object selected                    15:13:27
```

Figure 15-5: Switching to a UDO from the Parent Application

Exercise 15-3: Using the UDO in a parent application

Name: Circuit
Description:
In this exercise you are going to develop a parent application that will make use of the battery UDO. The application will simulate a simple electronic circuit composed of a battery and a switch.
Instructions:

1. Start a new application and save it as Circuit.rpd, in the same directory as Battery.udo.

2. Add a rocker switch to the layout.
3. Add the battery UDO to the layout.
4. Add two sibling modes to the mode tree, representing the different modes of the circuit: ***Open*** and ***Closed***.
5. Add transitions between the modes, which are triggered by the Rocker Switch.
6. When the circuit is closed, the battery is connected.
7. When the circuit is open, the battery is disconnected.

RapidPLUS XML support

RapidPLUS can save both applications and UDOs in an XML file format as well as the binary format. The XML format allows for use of version control systems. The following table summarizes the different extensions for each type of file:

	Binary	**XML**
Application	rpd	rxd
UDO	udo	uxo

Events

UDOs sometimes need a way to let the parent application know of a change in their status. For example, the battery may need the parent application to know it is low on power. The way to do that is by generating events that the parent application can respond to.

! **Important:**
The events we talk about are not Event objects. Event objects can only be used within the module (application or UDO) they were declared in. These events are events that the UDO exports as part of its logic interface.

Adding Events to a UDO

We add events to a UDO through the User Object dialog box. This dialog box holds the information about all four means of communication between the UDO and the Parent Application. To add events:

1. In the Object Layout of the UDO, double-click the background of the layout to open the Parameter Pane for the root object *self*.
2. Click the More button in the Parameter Pane to open the User Object dialog box.
3. Click the Events tab. Figure 15-6 shows the relevant section of the dialog box.

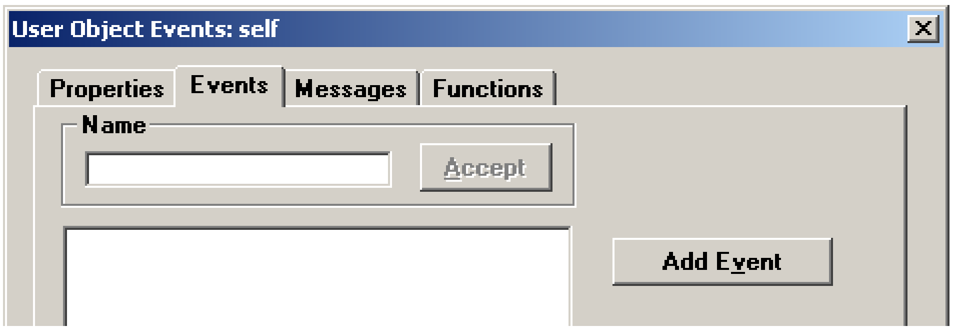


Figure 15-6: The Events tab of the User Object dialog box

4. Click the Add Event button. This will automatically append an event to the list with a default name.
5. Give the event a more descriptive name, and then click Accept (optional).

Now you can add logic to the UDO to generate the event when appropriate. The events you added appear as properties of the root object *self* in the Logic Palette.

Note:
Functions are the only means of communication that are not added to the UDO via the User Object dialog box. However, you can browse the exported functions within the dialog box.

Exercise 15-4: Adding events
Name: Battery
Description:
In this exercise you are going to add two events to the battery UDO. One will be generated when the battery is running low on power, e.g., when there is less than 20% power left in it, and the other will be generated when the battery becomes dead.
Instructions:

1. From the application Circuit.rpd, switch to Battery.udo.
2. Open the User Object dialog box.
3. Add two events:
   - One for indicating that the battery is low on power.
   - One for indicating that the battery has died.
4. Add two modes to the mode tree, representing full and low power. Adapt the logic accordingly.
5. Generate the events in the appropriate modes.

Exercise 15-5: Responding to events
Name: Circuit
Description:
In this exercise you are going to adapt the Circuit application so that it responds to the events coming from the battery UDO.
Instructions:

1. Open Circuit.rpd. If you switched to Battery.udo, simply switch back to from the Project Components list.
2. Add a Lamp object to the layout.
3. Under ***Closed***, add three child modes representing the level of current in the system: ***<u>NormalCurrent</u>***, ***LowCurrent***, ***NoCurrent***.
4. Adapt the application to the following requirements:
   - Normally the level of the current is ***<u>NormalCurrent</u>***. In this mode, the Lamp should be constantly on.
   - When the battery is low, the level of current is ***LowCurrent***. In this mode the Lamp should blink.
   - When the battery is dead, the level of current is ***NoCurrent***. In this mode the Lamp should be off.

Properties

The third form of communication between the UDO and its hosting parent application is the transfer of data through properties of the UDO. Properties convey different information about the object in several forms of data. Although they may be used for bi-directional information flow, their main purpose is to expose specific information on the UDO to its parent application.

Adding Properties to a UDO

As with events, we add properties through the User Object dialog box. To add a property:

1. In the Object Layout of the UDO, double-click the background of the layout to open the Parameter Pane for the root object *self*.
2. Click the More button in the Parameter Pane to open the User Object dialog box.
3. Click the Properties tab. Figure 15-7 shows the relevant section of the dialog box.
4. In the Add Property buttons group, click the appropriate button depending on the type of data the property will hold. This opens the appropriate data type dialog box.—the same dialog box you use when adding data objects in the layout. For this example, click the String button.

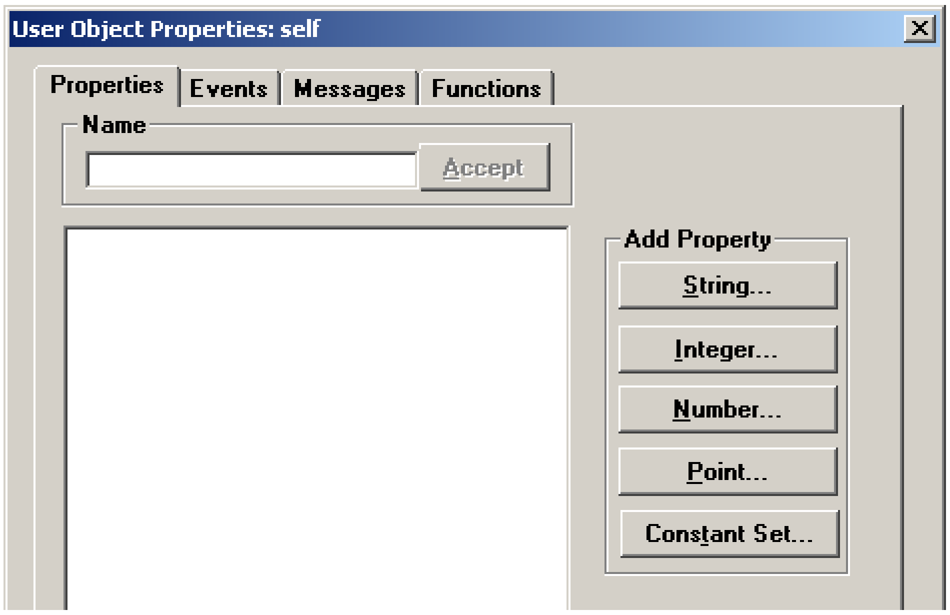
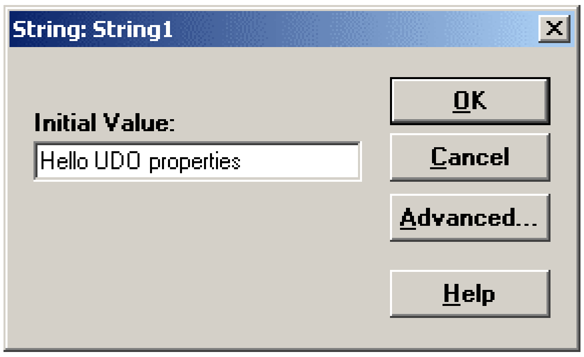


Figure 15-7: The Properties tab of the User Object dialog box

5. Edit the value of the new property in the dialog box. For this example, set the initial value of the string property to "Hello UDO properties". This is illustrated by Figure 15-8. When done, click OK.



Initial Value: Hello UDO properties

Figure 15-8: Setting the initial value of a String property

6. The property is added to the list of properties with a default name composed of its type and a number. Give the property a more descriptive name, and click Accept.

You can now add logic to the UDO according to your UDO's needs.

Exercise 15-6: Adding a property

Name: Battery

Description:

In this exercise you are going to add a property to the battery UDO that will hold the name of the active mode within the UDO. For example, if the battery is disconnected, the property will hold the text "Disconnected".

Instructions:

1. From the application Circuit.rpd, switch to Battery.udo.
2. Open the User Object dialog box.

3. Add a String Property and name it ModeName_Str.
4. In the Logic Editor, add logic to change the value of the property in the appropriate places.

Exercise 15-7: Using properties
Name: Circuit
Description:
In this exercise you are going to adapt the Circuit application so that it makes use of the property you defined for the battery UDO.
Instructions:

1. Open Circuit.rpd.
2. Add a text display object to the layout. Set the number of the characters in a line to a value that will fit the entire name of each mode in the battery UDO.
3. Add a mode activity to the root mode of the circuit application that sets the display's contents to the battery UDO's *ModeName_Str* property.

Important:
In simulations, mode activities are only executed if there is a change in the state of the objects that are involved in the activity. This does not apply to generated code for embedded systems, in which the activity is executed constantly regardless of the state of the objects involved. In this case, such activities are considered a performance hazard.

Messages

The last means of communication between the UDO and the parent application is through *messages*. The UDO defines the structure of the message, and both it and the parent application can send messages to each other.
A message is actually a set of data fields combined within a *structure*. This structure in turn resides within a *union*. The union holds several messages (structures). All the messages within a union share the same memory. This means that only one message in each union can be active at any given time.

Adding Messages to a UDO

As with events and properties, messages are defined via the User Object dialog box. To add a message:

1. In the Object Layout of the UDO, double-click on background of the layout to open the Parameter Pane for the root object *self*.
2. Click the More button in the Parameter Pane to open the User Object dialog box.
3. Click the Messages tab. Figure 15-9 shows the relevant section of the dialog box.

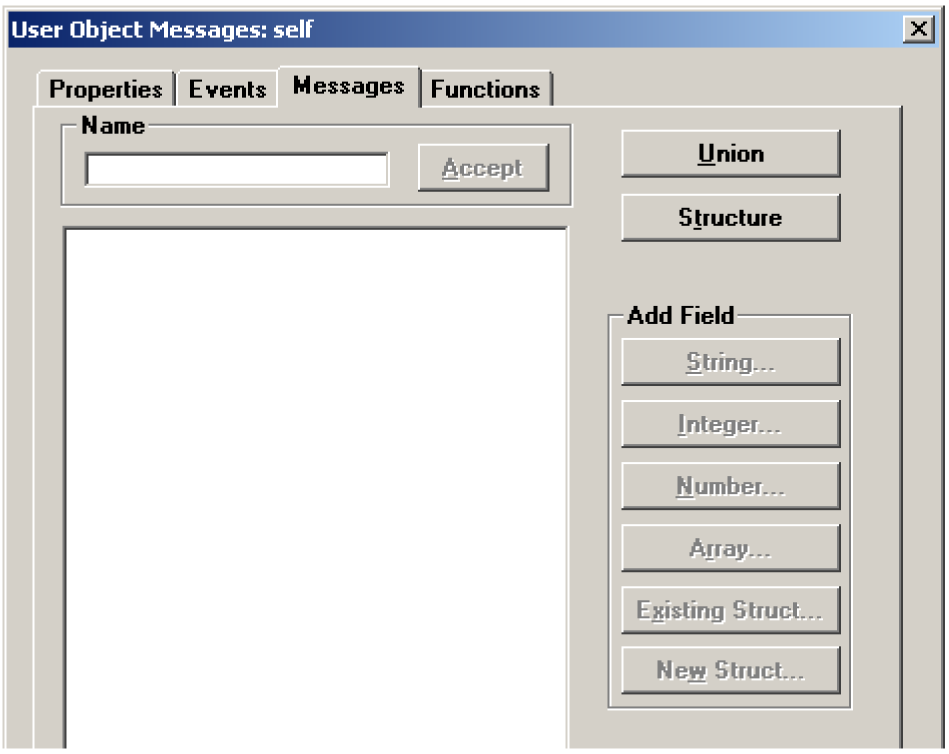


Figure 15-9: The Messages tab of the User Object dialog box

4. Click the Union button. This will add a new union to the list and give it a default name. Give the union a name that best describes the group of messages that will be defined in it. For example, Update_Msg would be a good name for a union of different updating messages. When done, click the Accept button.
5. Select the union in which you want to create the message, and then click on the New Struct button. This will open the SubStructure dialog box, as shown in figure 15-10.

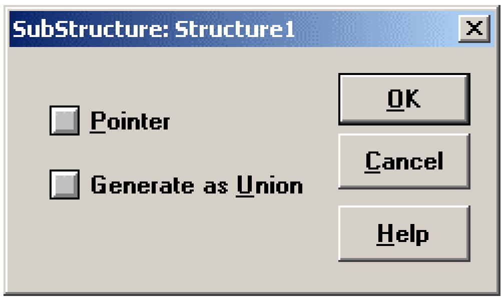


Figure 15-10: The SubStructure dialog box.

6. In the SubStructure dialog box, you define the method of memory allocation that will be used for holding the data of the structure, and whether or not the structure fields will be generated as a union.

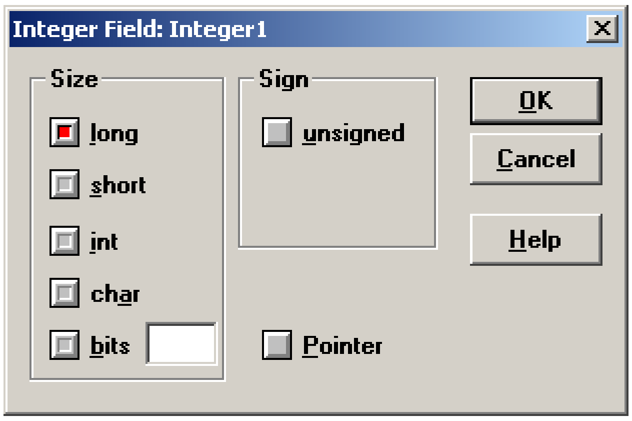
There are two methods for memory allocation:

- **Buffer**—the Pointer checkbox is cleared (this is the default method). In this case, the union holds the entire structure, that is, RapidPLUS allocates enough memory to hold the structure within the union.
- **Pointer**—the Pointer checkbox is selected. In this case, the union only holds a pointer to the actual structure, which resides somewhere else in the system's memory.

In both cases, RapidPLUS allocates the memory for the structure itself; the difference is how the memory is allocated.

Note:
The size of a union is determined by the size its largest member, be it a pointer to a structure or an actual structure.

7. When you are done with the settings in the SubStructure dialog box, click OK. This adds the new structure under the selected union. Note that the structure is slightly indented.
8. Give the structure an appropriate name, representing the message it conveys. For example, WaterLevel may be a good name for a message that relates to the water level in a hydraulic mechanism. When done, click the Accept button.
9. With the appropriate structure selected, add the different fields of data to the structure by clicking the different type buttons and editing the type's specific characteristics. For this example, add a single field of type integer.
10. Give each field a descriptive name. For this example, the integer field will be named Value_Int. Figure 15-11 shows the characteristics of the Integer type.


Integer Field: Integer1

Size: [✓ long] short int char bits

Sign: unsigned

Pointer

Figure 15-11: The characteristics of an integer field

Note:
You can define structures outside of a union, but such structures will only be used as type definitions. You can define messages of such types or even use them as fields within messages by clicking the Existing Struct button and selecting the desired type in the dialog box that appears.

Preparing, Sending, and Receiving Messages

Before a UDO or its parent application can send or receive a message, the message must be prepared and activated. Keep in mind that a union can hold several different messages, but only one of them can be active at any given time.
In order to activate a message, you simply need to assign a value to one of its fields. You assign values to the fields of a message one by one. Figure 15-12 shows a field being selected for assignment in the Logic Palette.

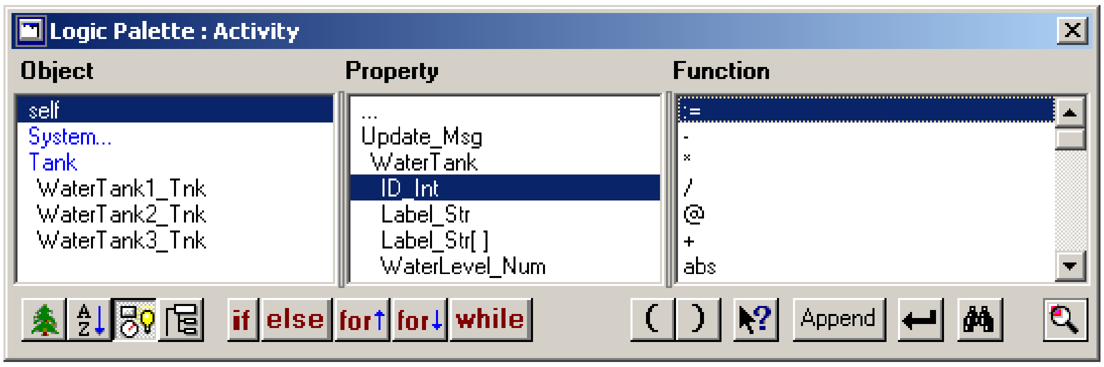


Figure 15-12: Selecting a field for assignment in the Logic Palette

Like functions, events, and properties, the messages are found under the root object *self* of the UDO. From the parent application, expand the UDO to view the messages.
Once you set up all the fields of a message, you are ready to send it. In order to do so, select the message and append the *send* function to the logic. Continuing with the example of the water tank, the syntax would be similar to this:

self.*Update_Msg.WaterTank* **send**

The message is sent. This causes an event to be generated on the receiving side. For example, if the UDO sent the message, the parent application receives an event and can act upon it. The trigger defined by the event looks like:

TanksController.*Update_Msg.WaterTank* **messageReceived**

In this case, TanksController is the name of the UDO in the parent application.
If the union holds more than one structure, i.e. more than one message can be sent with it, than a receiver of the messages can respond to any message sent with the union using the *'anyMessageReceived'* event trigger of the union. In this case the syntax would look like:

TanksController.*Update_Msg* **anyMessageReceived**

There are two copies of the message in the system's memory in simulations. One is on the UDO's side and one on the parent application's side. This means that once a message is sent, changing the values of its fields in one side does not affect the values in the other side.

Exercise 15-8: Messaging

Name: Battery

Description:

In this exercise you are going to add a message to the battery UDO. The message will only contain the power level of the battery, as an integer value.

Instructions:

1. From the application Circuit.rpd, switch to Battery.udo.
2. Open the User Object dialog box.
3. In the Messages tab, add a union and name it Update_Msg.
4. Add one new structure to the union and name it PowerLevel.
5. Add one unsigned integer field to the structure and name it Value_Int.
6. Add the appropriate logic to the UDO to prepare and send the message. The message should tell the receiver thebattery's power level.
7. In the entry activity of the root mode, prepare and send the message once.

Exercise 15-9: Receiving and handling a message

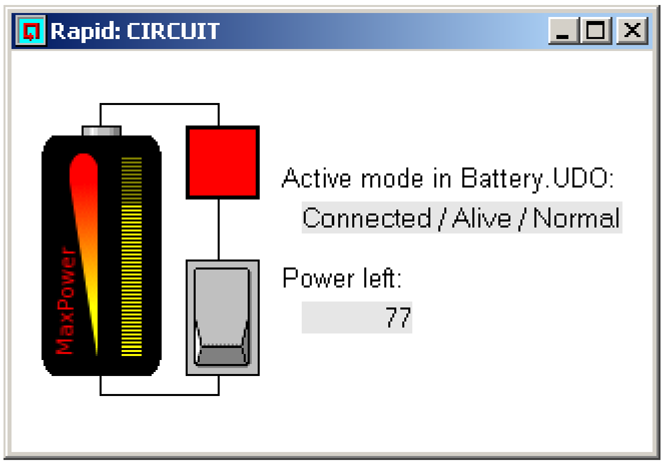
Name: Circuit

Description:

In this exercise you are going to adapt the Circuit application so that it will respond to messages that come from the battery UDO. The information received will be displayed on a new text display object.

Instructions:

1. Open Circuit.rpd.
2. Add a new text display object to the layout. Set the number of the characters in line to 3.
3. Adapt the Circuit application so that it displays the power level of the battery UDO in the new text display object.



Active mode in Battery.UDO:
Connected / Alive / Normal
Power left:
77

Figure 15-13: The Circuit application running as a standalone simulation

Day 3 Summary

- Day 3 Recap
- Exercise

Day 3 Recap

As its name implies, this day was mainly concerned with the introduction of User-Defined Objects (UDOs).
Chapter 13 provided an explanation of user functions. This topic, though not specific to use with UDOs, is closely connected to UDOs. The chapter stated the two function types, activity and condition functions, walked through how to create user functions, and explained how to use them.
Chapter 14 presented the Graphic Display Object (GDO). Though not directly connected to UDOs, this topic is important due to the growing popularity of graphic displays in modern electronic systems. The chapter covered the types of GDOs supported in RapidPLUS and how to use them.
Chapter 15 gave a broad introduction to UDOs, listed and explained the four means of communication between a UDO and its hosting parent application, and guided the learner through building a simple UDO from scratch.

Exercise

Exercise: UDO Logic Interface
Name: Editor1
Description:
To conclude this day you will now build an application with several UDOs, not just one. The application will simulate a simple text-editing device, constructed from a screen, a keypad, and a system clock.
The system will be composed of three UDOs and a parent application. The UDOs will each encapsulate one of the three elements listed above. The parent application will use each UDO through its respective logic interface.
You will begin by creating three empty UDO files, and adding them to the parent application.
Instructions:

1. Start a new application and save it as EMB_Display.udo.
2. Start a new application and save it as EMB_Keypad.udo.
3. Start a new application and save it as SRV_SysClock.udo.
4. Start a new application and save it as Editor1.rpd.
5. Add the three UDOs to the application. Name them as follows:

UDO	Name
EMB_Display.udo	EMB_DISPLAY
EMB_Keypad.udo	EMB_KEYPAD
SRV_SysClock.udo	SRV_SYSTEMCLOCK

6. Switch to EMB_DISPLAY and build it according to the following requirements:
    - The UDO is composed of a 10-character text display object of size 220@35.
    - The text on the display appears in Courier New font, size 28.
    - The UDO exports one function called *draw* that receives a string as an argument and draws it on the display.
7. Switch to EMB_KEYPAD and build it according to the following requirements:
    - The UDO is composed of four square pushbuttons: three of them are size 40@40 and labeled A, B, and C; and one is size 70@40 labeled Clr. Arrange the pushbuttons from left to right.
    - When any one of the pushbuttons is pressed, the UDO generates an event called *KeyPressed*.
    - The UDO also exports a property as part of its interface called LastKeyPressed_Int that is equal to a numeric code representing the last key that was pressed. The codes range from 1 to 4.
8. Switch to SRV_SYSTEMCLOCK and build it according to the following requirement:
    - The UDO sends a message to the parent application every second with the new time (hours, minutes, and seconds).
9. Switch back to the parent application.
10. Arrange the graphic UDOs in an esthetically pleasing way and add a filled frame in the background.
11. Build the application according to the following requirements:
    - By default, the system is ***Ready*** for input and the display shows the system's clock. Use the *formattedAs* function of the integer data type to properly display the data. Use the following format to the display the time: HH:MM:SS.
    - When one of the letter pushbuttons is pressed, the system goes into ***Editor*** mode in which the display shows the edited text.
    - Each letter pushbutton appends its corresponding letter to the text.
    - The maximum length of the text is 20 letters but only the last 10 are shown on the display.
    - When the Clr pushbutton is pressed, one letter is erased from the text.
    - If the entire text is erased, the display goes back to showing the system's time, and is again ***Ready*** for input.

Day 4

User-Defined Objects Methodology

Chapter 16

Holders and Dynamic Memory Allocation

- Holders
- Safety Mechanism
- Dynamic Memory Allocation

Holders

What is a Holder?

Chapter 11, “Data Objects,” stated that a holder is a data object that acts as a pointer to other active objects. This chapter examines what holders are used for and how to use them.

A holder object holds other objects. By doing so, the holder object exhibits the same set of functions exhibited by the held object along with its native functions. This is useful when you have several objects of the same type in an application being used in the same manner. Instead of duplicating the logic for each such object, simply write it once for the holder and then set the holder to hold the specific object required each time.

Another use of holders, in the context of UDOs, is that a holder can be set to hold a specific object type, without actually holding such an object initially. This provides the ability to set a holder within one UDO, and set it to hold another UDO without nesting the latter in the former, but by passing it as an argument to an initialization function of the former. In this way, different UDOs under the same parent application can use one another, via holders.

Creating and Using Holders

Creating a Holder

1. Select the Holder Object from the Data Objects group. You will be asked to name the holder. Give the holder a descriptive name. For this example, the name will be Display_Hl.

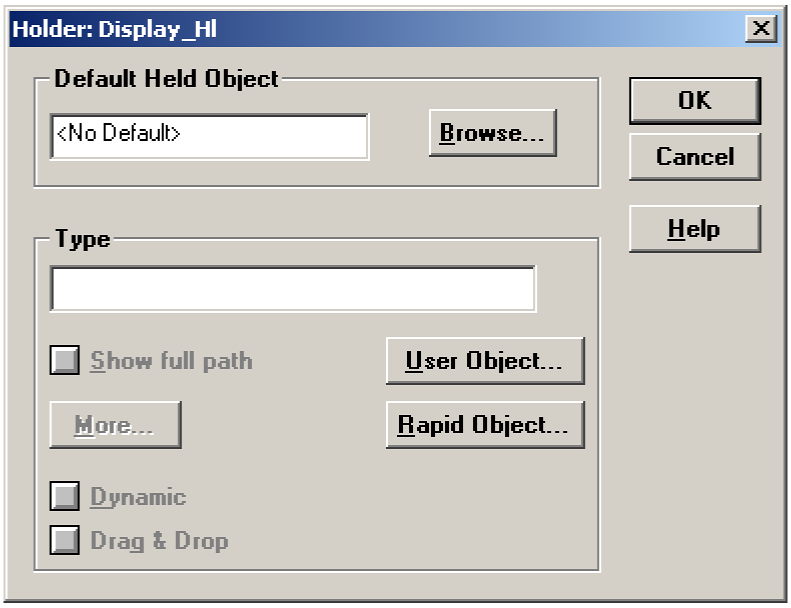


Figure 16-1: The Holder dialog box

2. Click the More button. This will open the Holder dialog box, as shown in Figure 16-1.
3. In the Holder dialog box, you can either:
   - Set the default object to be held by the holder. You can select any of the active objects found in the object layout of the holder's parent. This also sets the type of the holder.
   - Alternatively, you can select only the type of the object to be held by the holder, without selecting a default object. Click the Rapid Object button to select a RapidPLUS object, or click the User Object button to select from a list of UDOs.
   - In addition, if you choose to set only the type of objects to be held, you can also set the Dynamic and Drag & Drop properties of the holder.
4. When you are done, click the OK button to close the Holder dialog box.
5. Click the OK button to close the naming dialog box.

Using a Holder

A Holder exports four main functions as part of its interface: *'clear', 'hold', 'holdCopyOf',* and *'holdNew'.* We will discuss the last two in the last section of this chapter, "DMA: Dynamic Memory Allocation".

- ***clear***—releases the holder's hold of an object. As a result the holder is empty, i.e., it holds nothing. For example:

Display_Hl clear

- ***hold***—tells the holder to hold an object. The object must be of the type that was set when the holder was created. The object to be held is passed as an argument to the function. For example:

Display_Hl hold: EMB_DISPLAY

Note:
Neither of these functions can be used as a mode activity.

Once a holder is holding an object, you can make calls to the object's functions through the holder, just as you would do with the object itself.

Important:
Trying to make calls to object functions when the holder is empty will cause RapidPLUS to terminate the application with a runtime error.

Using a Holder Within a UDO

When you want one UDO to have a holder to another UDO in the application, the parent application must somehow connect between the holding UDO to the one being held, as neither is aware of the other. It is customary to have an initialization function exported as part of the holding UDO's interface that expects an argument of the UDO type to be held. It is then the parent application's responsibility to initialize the holding UDO with the respective held UDO, so that it can function properly.

Safety Mechanism

The problem with simply initializing a UDO to hold another UDO is that the holding UDO may refer to its holder before the held UDO is initialized, which in turn causes a runtime error. This calls for a safety mechanism to be incorporated into the initialization sequence.
A good solution to this problem is the addition of two modes in the holding UDO's mode tree. One mode represents the behavior exhibited by the UDO when it is not initialized. This usually amounts to nothing more than waiting for initialization and activation. The other mode represents the behavior exhibited by the UDO once it is ready to perform its purpose. The modes are usually named ***Idle*** and ***Active*** respectively. The ***Active*** mode is the parent of all other modes of the UDO.
Initialization starts when the UDO is ***Idle***. After initialization the UDO can safely shift to ***Active*** mode.

Exercise 16-1: Holders
Name: Editor2
Description:
In this exercise you are going to update the Editor application you developed in the summary exercise of day 3.
You will move the logic of the ***Ready*** and ***Editing*** branches from the parent application into two individual UDOs, called HMI_Ready and HMI_Editor. These UDOs will contain holders to the display, the keypad, and the system's clock. They will have exported initialization functions and Idle and Active modes. Only one of the new UDOs can be in Active mode at any given time.
Instructions:

1. Create a new directory and copy the following files from the summary exercise of day 3:
   - EMB_Display.udo
   - EMB_Keypad.udo
   - SRV_SysClock.udo
2. Start a new application and save it as HMI_Ready.udo.
3. Start a new application and save it as HMI_Editor.udo.
4. Start a new application and save it as Editor2.rpd.

5. Add all five UDOs to the application.
6. Arrange the graphic UDOs in an esthetically pleasing manner and add a filled frame behind them.
7. Develop HMI_Ready.udo according to the following requirements:
   - The UDO has ***Idle*** and ***Active*** modes.
   - The UDO exports three functions:
     - init_display: keypad: clock:
     - start
     - stop
   - The UDO exports one event called *activateEditor*.
   - When active:
     - The UDO sets the display to show the current system time.
     - If any of the letter keys is pressed, the UDO generates its exported event.
8. Develop HMI_Editor.udo according to the following requirements:
   - The UDO has ***Idle*** and ***Active*** modes
   - The UDO exports three functions:
     - init_display: keypad:
     - start
     - stop
   - The UDO exports one event called activateIdle.
   - When active:
     - The UDO sets the display to show the last 10 letters of the edited text.
     - Pressing any one of the letter keys causes the UDO to append the respective letter to the edited text.
     - The maximum length of the edited text is 20 letters.
     - Pressing the Clr key causes one letter to be cleared from the end of the edited text.
     - If the edited string is empty, the UDO generates its exported event.
9. Develop the parent application according to the following requirements:
   - The system can be in one of two modes: ***Ready*** or ***Editor***.
   - When in ***Ready*** mode, the HMI_Ready UDO is active.
   - When in ***Editor*** mode, the HMI_Editor UDO is active.

- Transitions between the two modes are dependent on an event triggered by the active UDO at each mode.

!

Important:
If the application is terminated with a runtime error, it may be due to referencing an inactive message of the SRV_SysClock UDO. You should prepare and send the message as an entry activity of the UDO's root mode to make it active.

Recommended conventions for UDO names

You have probably noticed the prefixes used for naming the different UDOs in the summary exercise of day 3 and in Exercise 16-1. These prefixes are part of a set of recommended conventions for UDO naming.
The following table associates the different prefixes with their purpose:

Prefix	Purpose
EMB	An embedded system component wrapper. Usually a hardware device such as a keypad or a display.
SRV	A service that by itself has no visual representation. Usually holds and manipulates the system's data. For example: the system's clock, a phonebook database, etc.
HMI	A component that handles a specific portion of the user interface of the application. For example, the main menu, a text editor, etc.

These prefixes and several others are used in e-SIM's MMI solution for mobile phones, and are recommended for use in other applications as well.

Dynamic Memory Allocation

RapidPLUS offers dynamic memory allocation (DMA) capabilities through holders. You can create instances of objects (active RapidPLUS objects and UDOs) through a holder at runtime. These instances will only exist for as long as a holder holds them. As with other DMA-supporting languages, the advantage of using DMA is that the memory is only being used when necessary. This is especially important for embedded systems.

Dynamically Creating and Freeing Objects

Creation of New Instances

As mentioned earlier in this chapter, the holder object exports two functions for creating objects dynamically at runtime. These are: *holdCopyOf* and *holdNew*. The following is a description of these two functions:

- ***HoldCopyOf***—creates a copy of the argument that is initially hidden and is located at the same position as the original. The original must exist in the application. For example:

  Display_Hl holdCopyOf: EMB_DISPLAY

- ***HoldNew***—creates a new instance of the type the holder is set to hold. There is no need for a previously allocated instance to be present in the application. For example:

  Display_Hl holdNew

Note:
When creating a new instance of a UDO that contains holders, you must initialize the holders before use.

Freeing Dynamically Created Instances

Objects that were dynamically created will cease to exist and the memory they occupied will be freed once no holder is holding them. This can happen if you clear the holder by using its clear function, or if the holder is told to hold a different object.

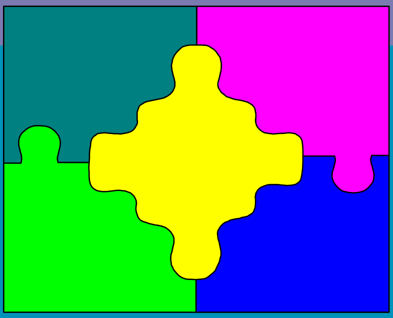
Exercise 16-2: Dynamic Memory Allocation

Name: Editor3
Description:
In this exercise you are going to introduce DMA to the Editor application, so that HMI_Editor.udo will only exist when needed.
Instructions:

1. Open Editor2.rpd and save it as Editor3.rpd.
2. In the Object Layout, add a new holder to the application and name it HMI_EDITOR_Hl.
3. Set the type of the holder to the proper UDO.
4. Using the Find and Replace function of the Logic Editor (under the Edit menu), replace all references to the nested UDO with references to the new holder and Remove the nested UDO.
5. Dynamically allocate and free the HMI_Editor UDO where appropriate.
6. Make sure the UDO is initialized before it is used.

Chapter 17

UDI: Interface-Only UDO



- What is a UDI?
- Declaring a UDI

What is a UDI?

An interface-only UDO, or UDI, is a UDO that is used to communicate with external modules in an embedded system. Such systems often contain hardware and software modules that need to interact with the RapidPLUS application, such as keypad or camera drivers. Since these are independent modules, the RapidPLUS application needs to provide connection points in order to communicate with them. These connection points are known as UDIs.
The UDI exports only an interface when it is being generated to code. The UDI can actually hold objects and logic, but these will only be relevant for simulation purposes and omitted in the code generation process.
The resulting generated code of a UDI contains empty functions. These are the connection points to the different independent modules. The developer in charge of integration, the *Integrator,* is then responsible for filling the functions with the relevant API calls of the independent modules.
In short, a UDI adapts a specific embedded hardware or software module to work with the RapidPLUS application. Figure 17-1 illustrates this:

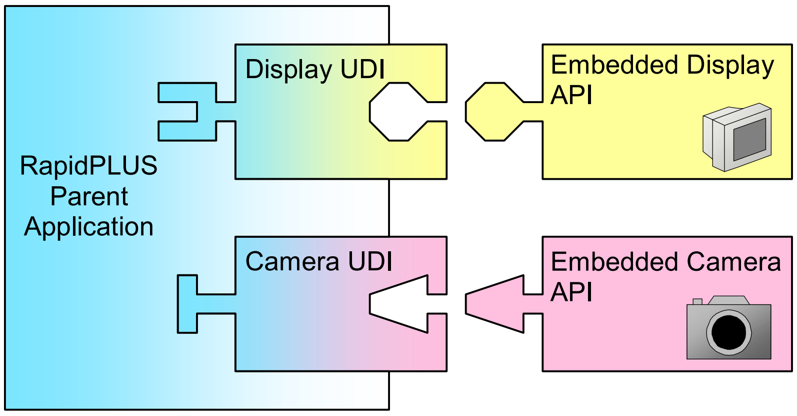


Figure 17-1: UDIs adapt embedded components to work with the RapidPLUS parent application

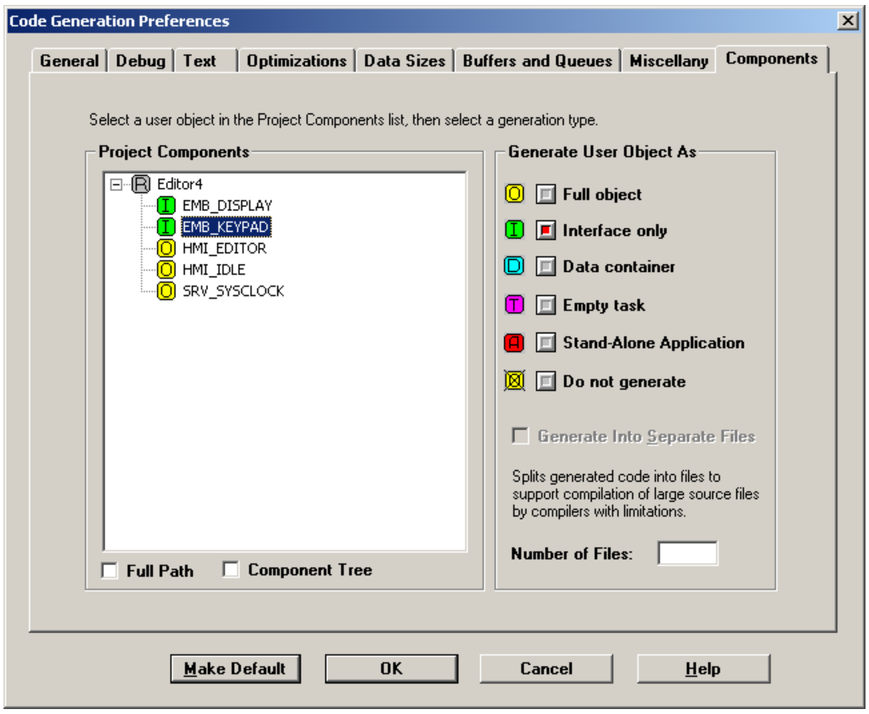
We will discuss the code generation and integration process in Chapter 20, “The Code Generation Process.”

Declaring a UDI

A UDO is considered to be a UDI only in the context of code generation. In order to generate a UDO as a UDI, you need to tell the RapidPLUS code generator that you only want to generate the interface for the specific UDO.

Marking a UDO as a UDI

1. From the parent application, select Code Generation Preferences from the Code menu of the Application Manager window. The Code Generation Preferences dialog box opens.
2. Switch to the Components tab.



Select a user object in the Project Components list, then select a generation type.

Project Components
- Editor4
  - EMB_DISPLAY
  - EMB_KEYPAD
  - HMI_EDITOR
  - HMI_IDLE
  - SRV_SYSCLOCK

Full Path / Component Tree

Generate User Object As
- Full object
- [✓ Interface only]
- Data container
- Empty task
- Stand-Alone Application
- Do not generate

Generate Into Separate Files

Splits generated code into files to support compilation of large source files by compilers with limitations.

Number of Files:

Figure 17-2: Setting the embedded components of the Editor application to be generated as UDIs.

3. From the list of Project Components, select the UDO you want to generate as a UDI and then select Interface only from the “Generate User Object As” group. The Icon next to the UDO’s name will change into a green frame marked with an “I” as shown in Figure 17-2.
4. When you are finished, click OK.

Note:
The Code Generation Preferences dialog box is used to set up a lot of different aspects of the code generation process. The different tabs in the dialog box will be covered in chapter 20, "The Code Generation Process".

Exercise 17-1: UDI
Name: Editor4
Description:
In this exercise you are going to set the embedded components of the Editor application for generation as UDIs.
Instructions:

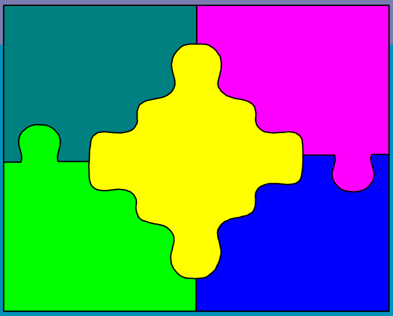
1. Open Editor3.rpd and save it as Editor4.rpd.

2. Set the following UDOs to be generated as UDIs:
   - EMB_DISPLAY.udo
   - EMB_KEYPAD.udo

Note:
Following the recommended conventions for UDO names given in Chapter 16, “Holders and Dynamic Memory Allocation,” the UDOs that will be generated as UDIs are those with “EMB” as their name prefix.

Chapter 18

UDD: Data Container UDO



- What is a UDD?
- Declaring a UDD

What is a UDD?

A data container UDO, or UDD, is essentially a UDO that only exports a message and is used for data exchange between two or more other UDOs. The UDD itself contains no objects or logic. Each one of the UDOs that exchange the data contain a holder to the UDD, through which they set the values of the different fields in the UDD's message. The message itself is never sent. Figure 18-1 illustrates this:

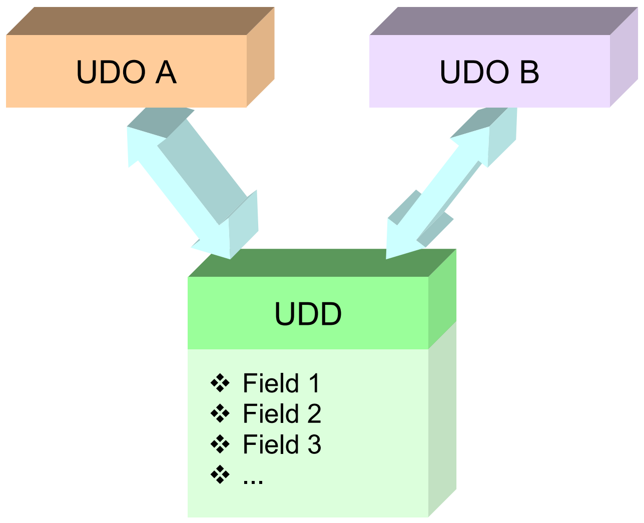


Figure 18-1: A UDD serves for data exchange between two UDOs

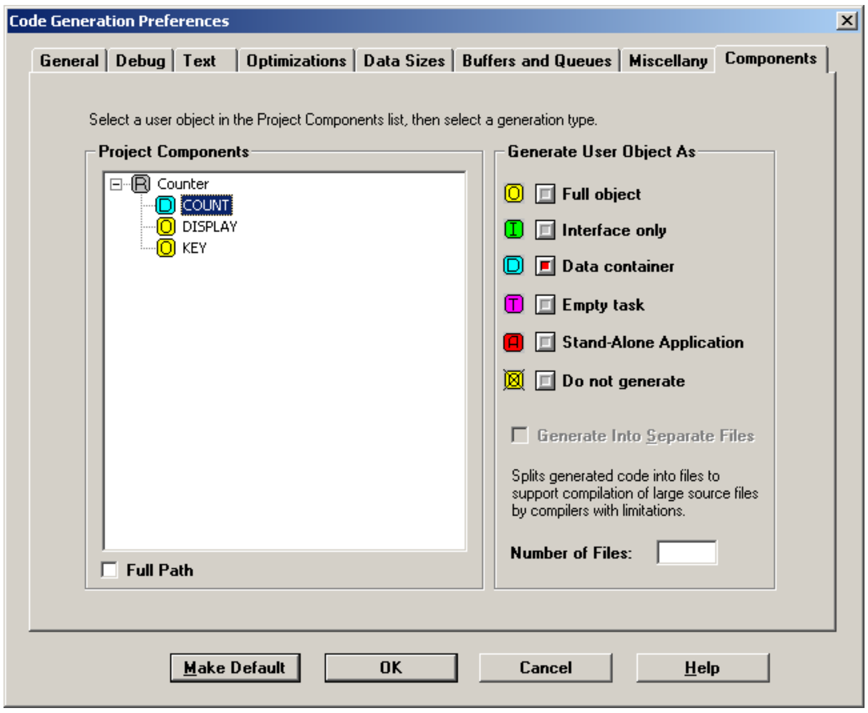
Note:
As mentioned in Chapter 15, "The Makings of a User-Defined Object," in simulations, a message has two buffers, one accessed from the UDO itself, and one accessed from outside (either directly or via a holder). In a UDD, only the outside buffer is used.

Declaring a UDD

As mentioned earlier, a UDD is simply a UDO that only exports a message construct. For code generation, you need to mark it as a UDD.

Marking a UDO as a UDD

1. From the parent application, select Code Generation Preferences from the Code menu of the Application Manager window. The Code Generation Preferences dialog box opens.
2. Switch to the Components tab.


Code Generation Preferences

General | Debug | Text | Optimizations | Data Sizes | Buffers and Queues | Miscellany | Components

Select a user object in the Project Components list, then select a generation type.

Project Components
- Counter
  - COUNT
  - DISPLAY
  - KEY

☐ Full Path

Generate User Object As
- ☐ Full object
- ☐ Interface only
- ☑ Data container
- ☐ Empty task
- ☐ Stand-Alone Application
- ☐ Do not generate

☐ Generate Into Separate Files

Splits generated code into files to support compilation of large source files by compilers with limitations.

Number of Files:

Figure 18-2: Setting a UDO to be generated as a UDD

3. From the list of Project Components, select the UDO you want to generate as a UDD and then select Data container in the “Generate User Object As” group. The Icon next to the UDO’s name will change into a cyan frame marked with a “D” as shown in Figure 18-2.
4. When you are finished, click OK.

Exercise 18-1: UDD

Name: Counter

Description:

In this exercise you are going to develop two UDOs that will exchange data through a shared UDD. One of the UDOs will write the data, while the other UDO will read the data.

Instructions:

1. Start a new application and save it as Key.udo.
2. Start a new application and save it as Display.udo.
3. Start a new application and save it as Count.udo.
4. Start a new application and save it as Counter.rpd.
5. Add the three UDOs to the application
6. Switch to the Count UDO and add a message to it. The message contains one Integer field named Count_Int.

7. Switch to the Key UDO and adapt it as follows:
   - The UDO has ***Idle*** and ***Active*** modes.
   - Add the following objects to the layout:
     - Pushbutton.
     - A holder for a UDO of type Count.udo.
   - The holder should be initialized by an exported function.
   - When active, every push of the pushbutton increases the value of the Count_Int field of the held UDD.
8. Switch to the Display UDO and adapt it as follows:
   - The UDO has ***Idle*** and ***Active*** modes.
   - Add the following objects to the layout:
     - Text display.
     - Timer set to 500 ms.
     - A holder for a UDO of type Count.udo.
   - The holder should be initialized by an exported function.
   - When active, the display is updated on every timer tick to show the current value of the Count_Int field of the held UDD.

Number:
Outgoing call number:
RSSI
Security settings
SIM Ready PIN 1 PUK 1 Missing
PIN code 1234 PUK code 12345678
Network selection
- auto - manual - manual then auto
Operator long name Orange BU
Operator short name ORANGE
Operator number 42501 Network ID 1
Off Send error
SIM state PIN 2 PUK 2

Day 4 Summary

- Day 4 Recap
- Summary Exercise

Day 4 Recap

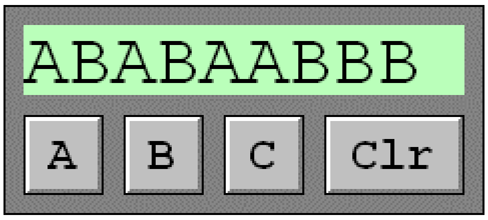
As opposed to Day 3, which dealt with the basics, Day 4 was more concerned with advanced topics of User-Defined Objects and the methodologies of using them.
Chapter 16 covered the topic of holders and how they are used in RapidPLUS applications and UDOs. It then presented a safety mechanism for UDOs that contain empty holders to other UDOs, involving an idle mode and an active mode. The chapter concluded with a discussion of dynamic memory allocation (DMA) in RapidPLUS.
Chapter 17 explained Interface-only UDOs (UDIs), and how to declare a UDO for generation as a UDI. The chapter gave a first look at the code generation preferences dialog box.
Chapter 18 closed the day with an introduction to the concept of data container UDOs (UDDs), and how to prepare them for code generation.

Summary Exercise

Exercise: UDO Summary
Name: Editor5
Description:
In this exercise you are going to finalize the Editor application. The Editor itself will become a UDO, and it will exchange data with a new UDO representing a screen, by using a shared UDD.
Instructions:

1. Create a new folder and copy the files from Exercise 16-1 (Editor4) to it.
2. Open Editor4.rpd and save it as a UDO named Editor.udo.
3. Delete Editor4.rpd from the new folder.
4. Start a new application and save it as Screen.udo.
5. Start a new application and save it as UDD_Caption.udo.
6. Start a new application and save it as Editor5.rpd.
7. Add the following UDOs to the layout of Editor5:
   - Editor.udo
   - Screen.udo
   - UDD_Caption.udo
8. Switch to the UDD_Caption UDO and develop it according to the following requirements:
   - The UDO only exports a message containing one String field, named Caption_Str.

9. Switch to the HMI_Editor UDO, contained as a class (by a holder) in the Editor UDO, and adapt it according to the following requirements:
   - The UDO should contain a holder to an object of type UDD_Caption.udo.
   - The initialization function of the UDO should now initialize the new holder as well.
   - Every time the edited text is changed, the Caption_Str field of the held UDD_Caption object is updated.
10. Switch to the Editor UDO and adapt it according to the following requirements:
    - The UDO has ***Idle*** and ***Active*** modes.
    - The UDO contains a holder to an object of type UDD_Caption.
    - The holder should be initialized by an exported function.
    - Correct the call to the initialization function of the HMI_Editor UDO. Pass the local holder of UDD_Caption.udo as the new argument for the function
11. Switch to the Screen UDO and develop it according to the following requirements:
    - The UDO has ***Idle*** and ***Active*** modes.
    - The UDO contains a holder to an object of type UDD_Caption.udo.
    - The holder should be initialized by an exported function.
    - The UDO contains an EMB_Display object and a timer set to tick every 500 ms.
    - In ***Active*** mode, the EMB_Display UDO is updated on every timer tick to display the current value of the Caption_Str field of the UDD_Caption object held by the holder.
12. Adapt the parent application Editor5 to the following requirements:
    - The Caption_Str field of the UDD_Caption UDO is initialized to an empty sting.
    - Initialize and activate both the Editor and the Screen UDOs.



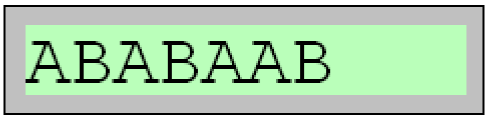


Figure S4-1: Editor5 running.
The screen’s periodic update is reflected by the displayed data.

Day 5

Code Generation Basics

Chapter 19

The Target Perspective

- The Structure of a Simulation
- Embedded Target Architecture
- Interfacing the Application
- The Target Perspective

The Structure of a Simulation

Before examining the architecture of an embedded target and how a generated RapidPLUS application interacts within an embedded system, you should look closely at the structure of a RapidPLUS application before it is generated to code, i.e., when it is still considered a simulation.

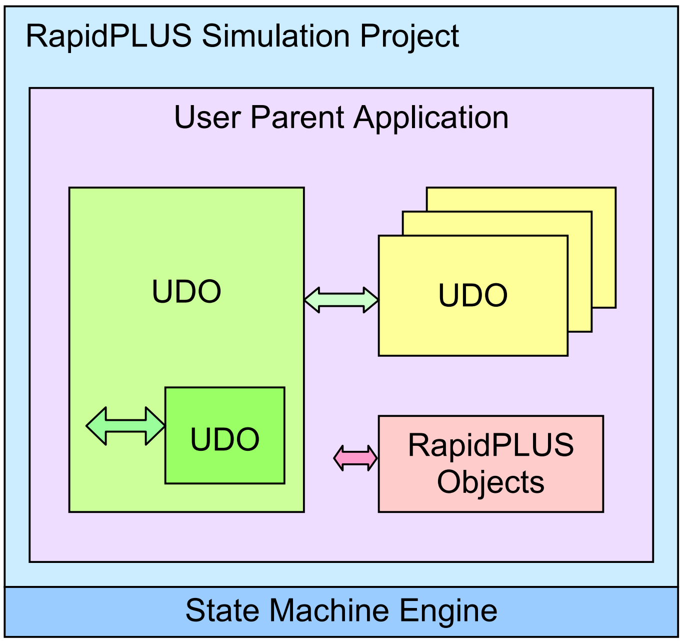


Figure 19-1: The structure of a simulation

As shown in Figure 19-1, the parent application contains native RapidPLUS objects and also—either directly or via holders—some UDOs in different configurations. The RapidPLUS state machine engine executes the entire simulation (application, UDOs, and native RapidPLUS objects).

Embedded Target Architecture

The embedded application generated by RapidPLUS runs as a task on top of the real-time operating system present on the target. Figure 19-2 illustrates the levels of the target architecture and where the RapidPLUS application sits.

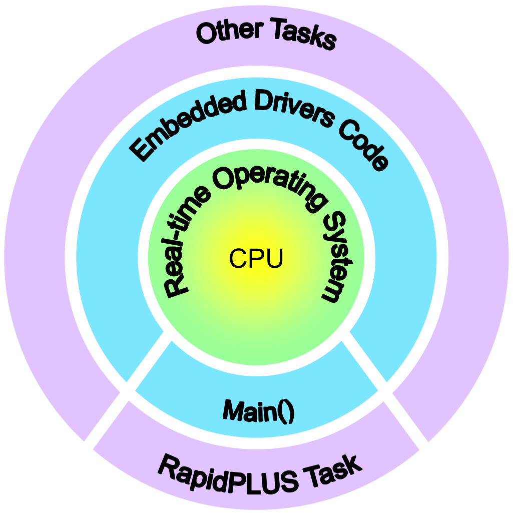


Figure 19-2: Layers of an embedded target

The real-time operating system (RTOS) is at the base of the target platform. The RTOS communicates with drivers and protocols. Both drivers and protocols are present in the system regardless of RapidPLUS.
The RapidPLUS task behaves like any other high-level task (application) in the system. RapidPLUS does not replace the main operating system.
RapidPLUS code interacts with the operating system on two levels:

1. **The RapidPLUS API**—consists of library functions to control the RapidPLUS engine.
2. **The Application API**—consists of user code integrated with the system drivers and links to other tasks.

The code generation process generates the application on two levels:

1. The first, implementing the application itself, is internally complete and does not need further integration. The code is composed of the RapidPLUS application and UDOs.
2. The second is the Application API, which is composed of an interface between the UDOs and the drivers, essentially the UDIs. The integration process takes place here.

Figure 19-3 illustrates how these parts interact within a complete embedded system.

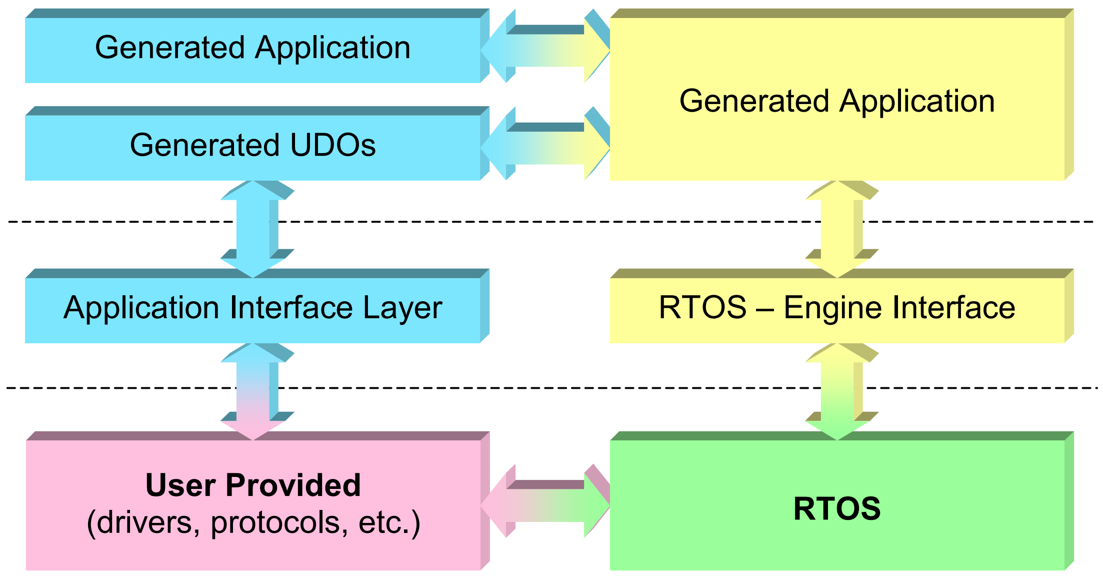


Figure 19-3: The target architecture

In general terms, the process of building an embedded application with RapidPLUS has two aspects. From RapidPLUS's point of view, it needs to translate the virtual simulation that the user built into ANSI-C source code for compilation. It also needs to generate the proper interfaces so that the application can communicate with the embedded hardware via that hardware's drivers. This part of the process is referred to as code generation.
The developer on the other part needs to "stitch" the embedded engine interface (RapidPLUS API) with the RTOS at the first level, and "stitch" the generated interfaces (Application API) with the appropriate API calls for the embedded modules. Eventually the developer is responsible for compiling and linking the application for the target.[LS2] This part of the process is referred to as integration.

Interfacing the Application

The code generation process converts the four elements of a UDO's Logic Interface to respective ANSI-C statements:

- Function calls from the parent.
- Macros for triggering events in the UDO.
- Get and Set macros for handling properties.
- Structured Messages into and from the parent, with macros to send them.

Figure 19-4 reexamines the direction of these interfaces from the parent application's point of view.

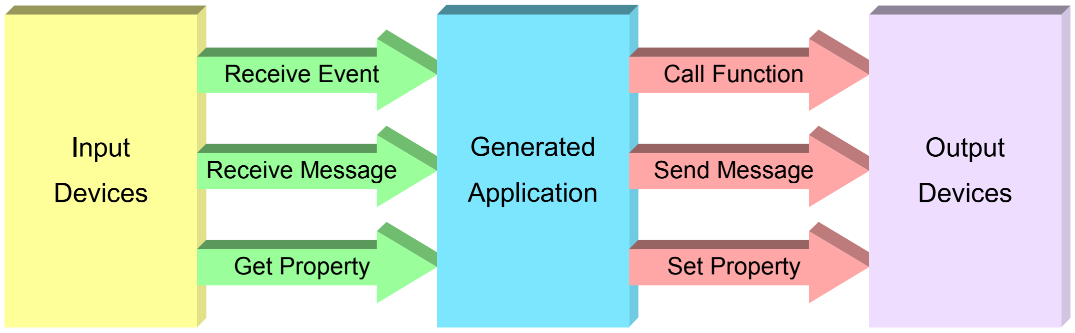


Figure 19-4: The generated interfaces

The Target Perspective

Figures 19-5 to 19-7 illustrate the differences in perspective between the simulation and the target for a password protected door locking system.

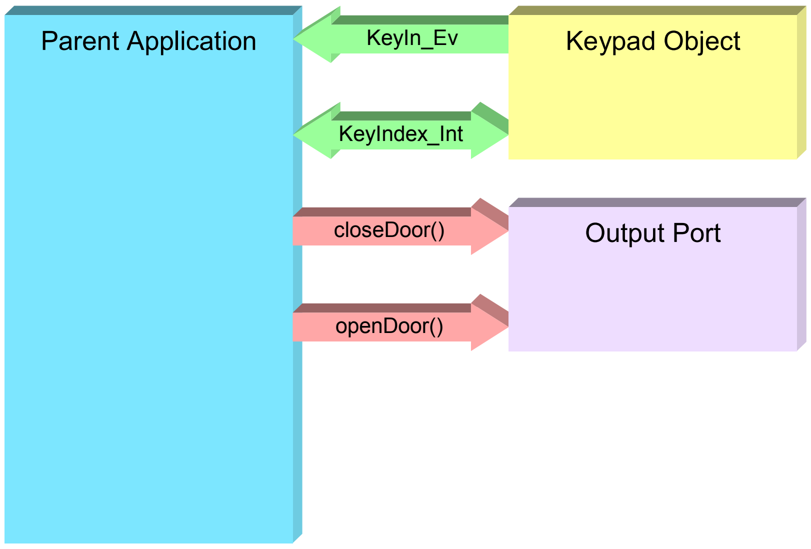


Figure 19-5: Device interfaces from the simulation perspective

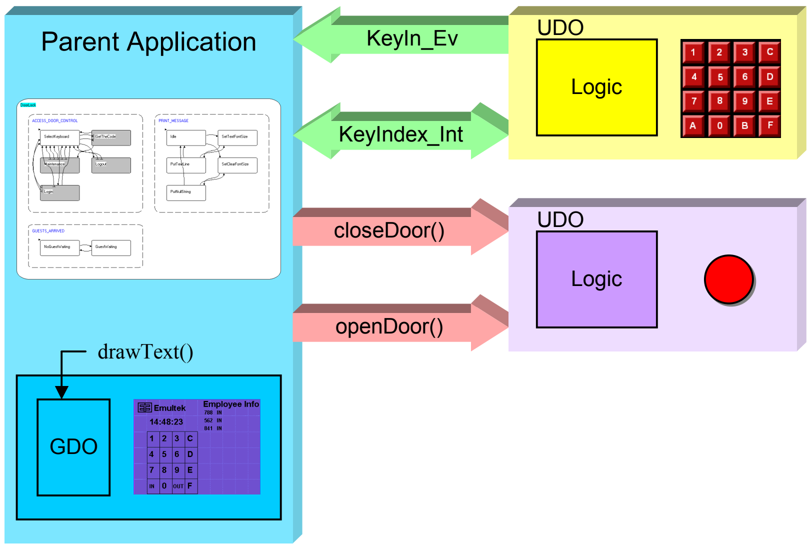


Figure 19-6: The simulation’s structure

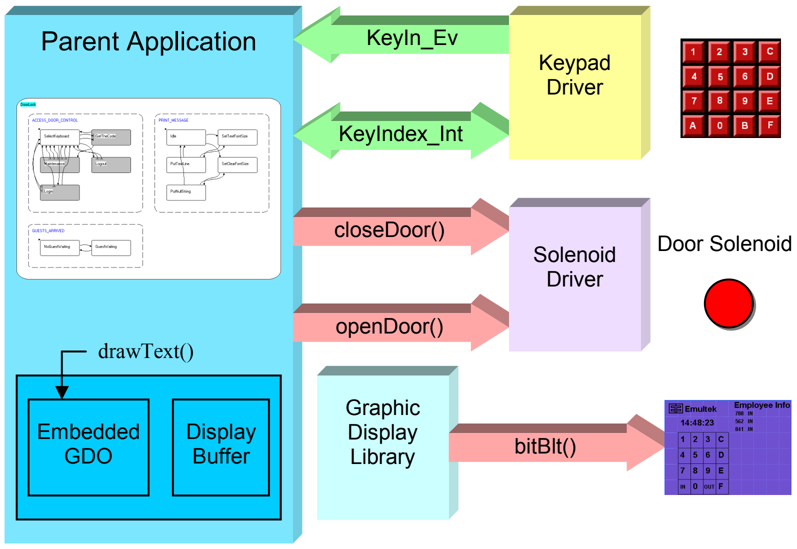


Figure 19-7: The target’s perspective

Chapter 20

The Code Generation Process

- Generating a Simple Application
- The Code Generation Preferences

Generating a Simple Application

Overview of the Process

The process of generating code from a RapidPLUS simulation and integrating it to the embedded target is fairly straightforward. The following steps are carried out:

- **Design and build the simulation for code generation**. You must take the fact that the simulation is going to be generated to code into account when developing it. In other words, you should design the interfaces through which your application will communicate with the embedded components and implement them as UDIs.
- **Set specific preferences of code generation for the project.** This is an important phase, where you prepare your project for the generation process.
- **Generate the code.** This is when the actual code is generated.
- **Integrate the interfaces.** In this step you "stitch" the UDIs to their respective embedded components' APIs, and also the RapidPLUS embedded engine to the RTOS.

In this chapter we will walk through this entire process for an extremely simple application called Simple.

Prerequisites

In order to complete the exercises in this chapter and in the following chapters you will need two things:

- Borland's command-line C compiler (with win32 support).
- A ready-made environment, for DOS integration.

Both can be found in the GivenResources folder of the course.

The Compile Environment Structure

The ready-made environments present in the GivenResources folder provide the following folder structure as shown in Figure 20-1:

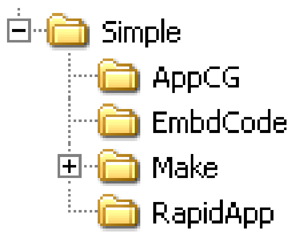


Figure 20-1: Project folder structure

- AppCG—contains the generated source code files.
- EmbdCode—contains the User API files, and the main program.
- Make—contains the makefiles for building the project.
- RapidApp—contains the RapidPLUS source application files.

Getting Started

Building the Application

Following the process overview described earlier, the first step is to develop the RapidPLUS application in the context of code generation. This means that the application will have to integrate with the hardware and RTOS. For the purpose of learning the process, our hardware will be a personal computer, and our RTOS will simply be DOS.

Note:
A personal computer is not an embedded system nor is DOS a RTOS.

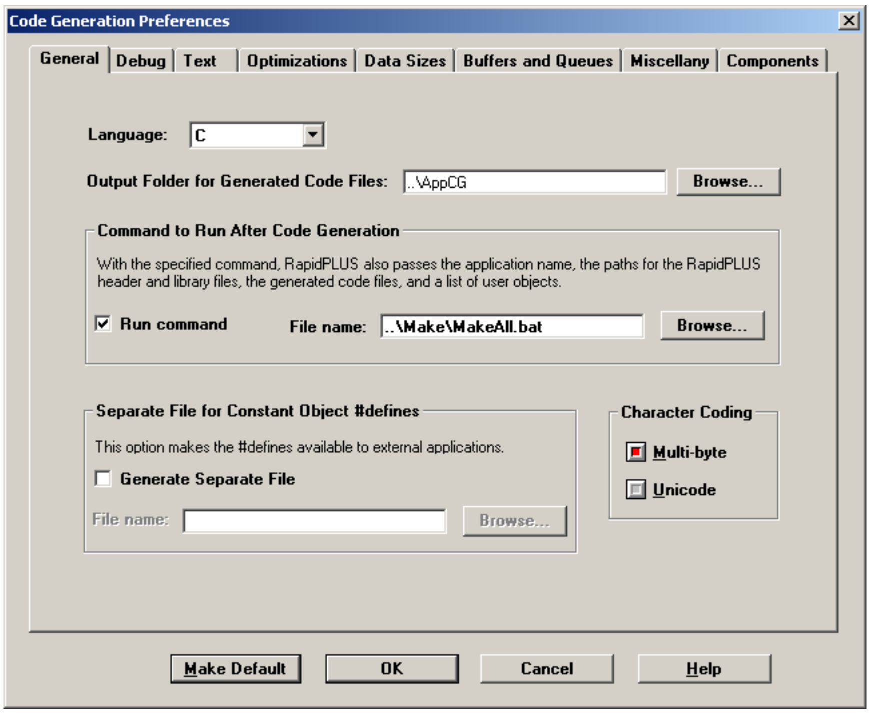
Exercise 20-1: Building an application for code generation
Name: Simple (Phase 1)
Description:
In this exercise you will develop a very simple application in the context of code generation. The application will draw a string of text on an embedded display, represented by a UDI.
Instructions:

1. Copy “Borland_5.5_Compile_Environment_Template_Dos” to a local folder and rename it “Simple.” This will be the project’s environment.
2. Open the file main.c in the EmbdCode subfolder and edit the first *#include* statement to include the file Simple.h.
3. Create a new application and save it as EMB_Display.udo, in the RapidApp subfolder.
4. Create a new application and save it as Simple.rpd in the RapidApp sub-folder.
5. Add the EMB_Display UDO to the application.
6. Switch to the EMB_Display UDO and adapt it to the following requirements:
   - Add a text display object to the layout.
   - The UDO should export a single function named *draw* that receives a string as an argument.
   - Implement the function so that when executed, the display will show the text passed as the argument.

7. Switch back to the parent application and adapt it according to the following requirements:
   - Upon execution, i.e., as an entry activity of the root mode, the application should call the *draw* function of the EMB_Display UDO, with “Hello CG!” as the argument.
8. Verify that the application does what it is supposed to in the Prototyper.

Setting a Few Preferences

The next step in the process is to set up our preferences for the code generation. To do so, we will revisit the Code Generation Preferences dialog box, presented initially in Chapter 17, “UDI: Interface-Only UDO.” For now we will just set a few preferences quickly and not get into too many details. A more detailed discussion of the different preferences will be given in the next section of this chapter.


Code Generation Preferences

General | Debug | Text | Optimizations | Data Sizes | Buffers and Queues | Miscellany | Components

Language: C

Output Folder for Generated Code Files: ..\AppCG

Command to Run After Code Generation

With the specified command, RapidPLUS also passes the application name, the paths for the RapidPLUS header and library files, the generated code files, and a list of user objects.

[✓] Run command File name: ..\Make\MakeAll.bat

Separate File for Constant Object #defines

This option makes the #defines available to external applications.

[ ] Generate Separate File

File name:

Character Coding

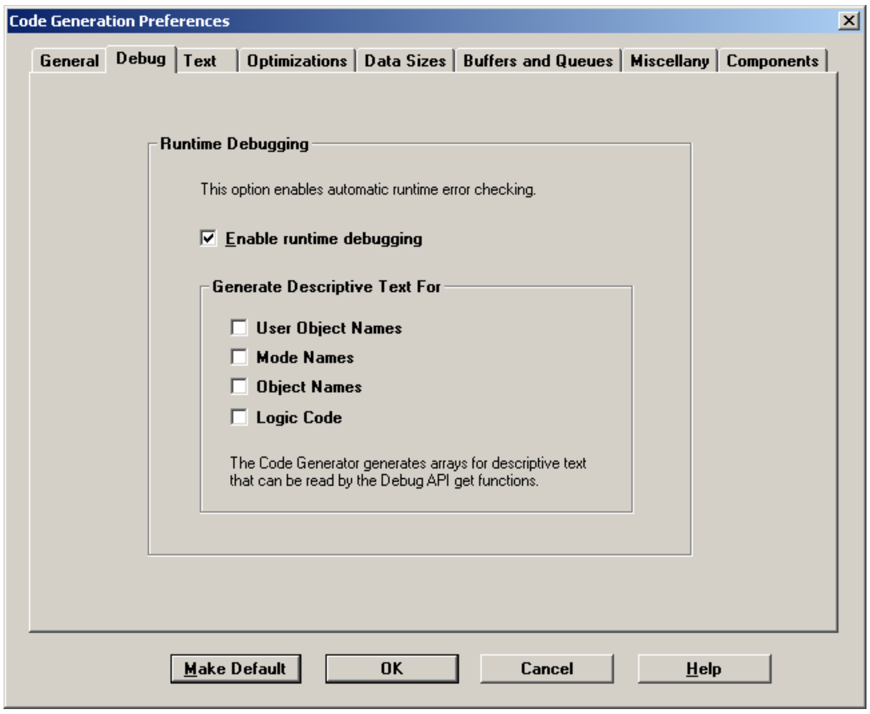
[■] Multi-byte

[ ] Unicode

Figure 20-2: General preferences tab

1. From the Code menu in the main window of RapidPLUS, select Code Generation Preferences to open the appropriate dialog box.
2. In the General tab (see Figure 20-2), set the following options:
   - Set “Output Folder for Generated Code Files” to the AppCG subfolder of the Simple folder. Usually, setting the value to ..\AppCG is sufficient.
   - Select Run command and set File name to point to the MakeAll.bat file in the Make subfolder of the Simple folder. Usually, setting the value to ..\Make\MakeAll.bat is sufficient.

3. In the Debug tab, select “Enable runtime debugging” (see Figure 20-3).


Code Generation Preferences

Runtime Debugging

This option enables automatic runtime error checking.

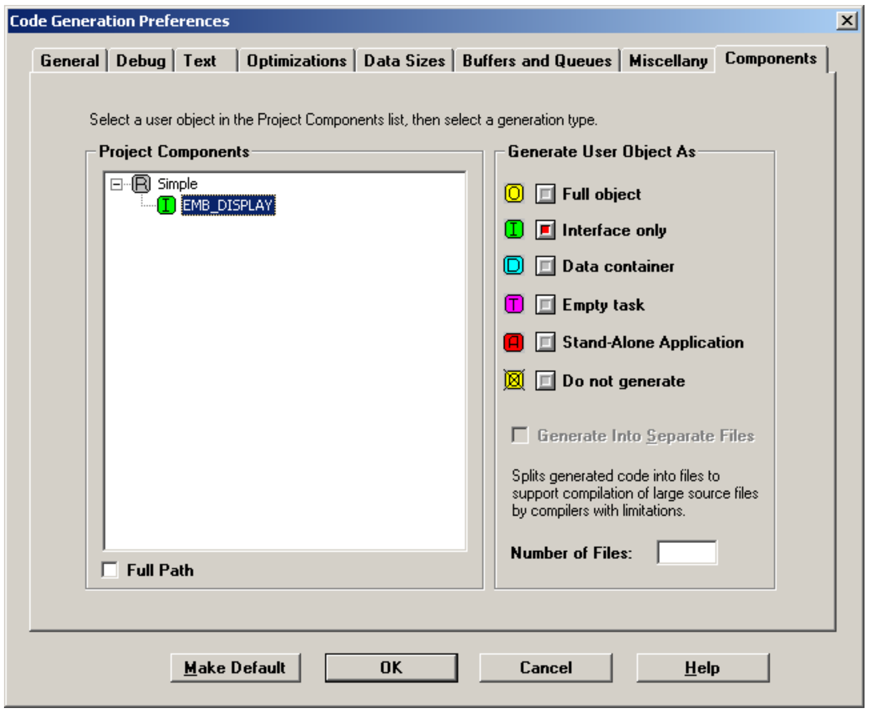
[✓] Enable runtime debugging

Generate Descriptive Text For

[ ] User Object Names
[ ] Mode Names
[ ] Object Names
[ ] Logic Code

The Code Generator generates arrays for descriptive text that can be read by the Debug API get functions.

Figure 20-3: Debug preferences tab


Code Generation Preferences

Select a user object in the Project Components list, then select a generation type.

Project Components

Simple
EMB_DISPLAY

[ ] Full Path

Generate User Object As

[ ] Full object
[✓] Interface only
[ ] Data container
[ ] Empty task
[ ] Stand-Alone Application
[ ] Do not generate

[ ] Generate Into Separate Files

Splits generated code into files to support compilation of large source files by compilers with limitations.

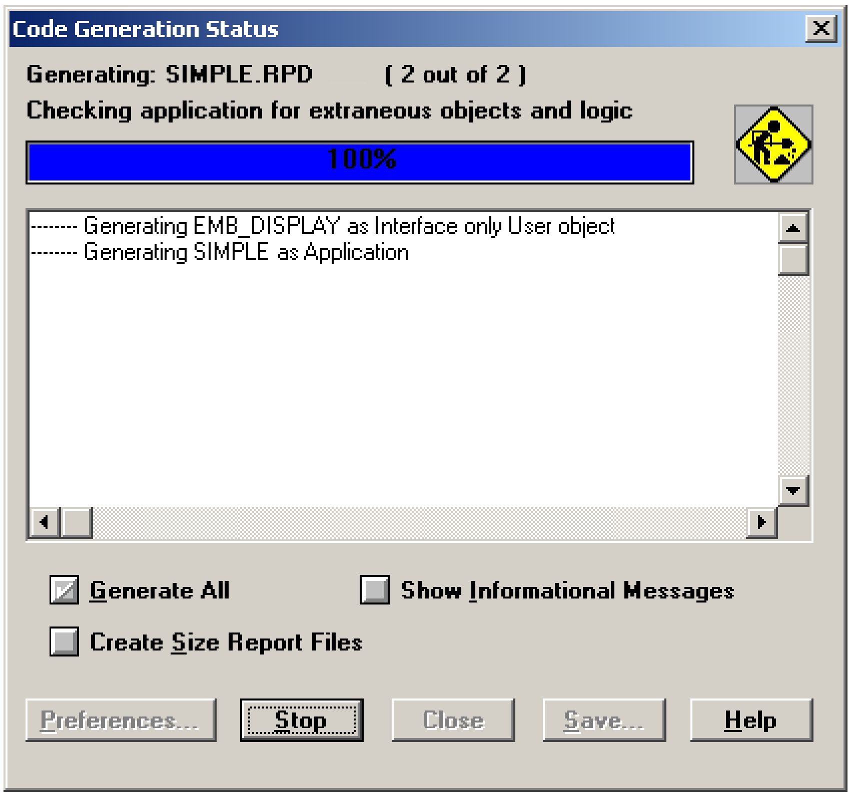
Number of Files:

Figure 20-4: Components preferences tab

4. In the Components tab, highlight EMB_DISPLAY and then select Interface only (see Figure 20-4).
5. Save the application. This saves the preferences in the application file.

Generating the Code

The third step in the process is to actually generate the code.



Generating: SIMPLE.RPD [2 out of 2]
Checking application for extraneous objects and logic

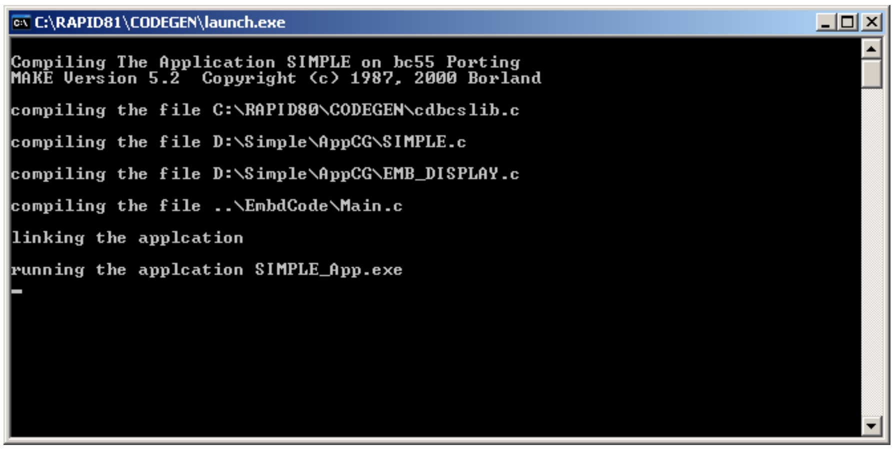
```
-------- Generating EMB_DISPLAY as Interface only User object
-------- Generating SIMPLE as Application
```

[✓] Generate All
[ ] Show Informational Messages
[ ] Create Size Report Files

Figure 20-5: Generating the code

1. From the Code menu of the Application Manager, select Generate Code. The Code Generation Status dialog box opens.
2. Click the Start button to start code generation. During the process, several messages appear. They may include progress reports, warnings, and errors. Figure 20-5 shows the process.

If no errors occurred, the MakeAll.bat file will cause to program to compile, link, and run. Figure 20-6 shows the result of this operation.



```
Compiling The Application SIMPLE on bc55 Porting
MAKE Version 5.2  Copyright (c) 1987, 2000 Borland

compiling the file C:\RAPID80\CODEGEN\cdbcslib.c

compiling the file D:\Simple\AppCG\SIMPLE.c

compiling the file D:\Simple\AppCG\EMB_DISPLAY.c

compiling the file ..\EmbdCode\Main.c

linking the applcation

running the applcation SIMPLE_App.exe
_
```

Figure 20-6: Running the Simple application for the first time

Integrating the Display

As you can probably see from figure 20-6, although the application is running, we are not welcomed with the “Hello CG!” message we were hoping for. This is due to the fact that we have not yet integrated the interface of EMB_DISPLAY with the actual display.

Even so, we did reach a milestone. If this small program works on your target, even without the UDIs being integrated, it means that the RapidPLUS embedded engine is suitable for your embedded system.

In order to integrate the display, we need to add some code:

1. In the AppCG subfolder, open the file named emb_display.c.
2. At the end of the file you will find the interface for the *draw* function that the display UDI exported. The function should look like Listing 20-1.

```
void EMB_DISPLAY_R15673_draw_ ( EMB_DISPLAY* udo,
                                const pchar  Parm_str)
  {
  /******************************************************************
   * subroutine draw: <String:str>
   * begin
   * Screen_Dsp.contents := <str> ;
   * end
   ******************************************************************/
/******** RapidUserCode BEGIN EMB_DISPLAY_R15673_draw_ ********/
/******** RapidUserCode END   EMB_DISPLAY_R15673_draw_ ********/
  }
```

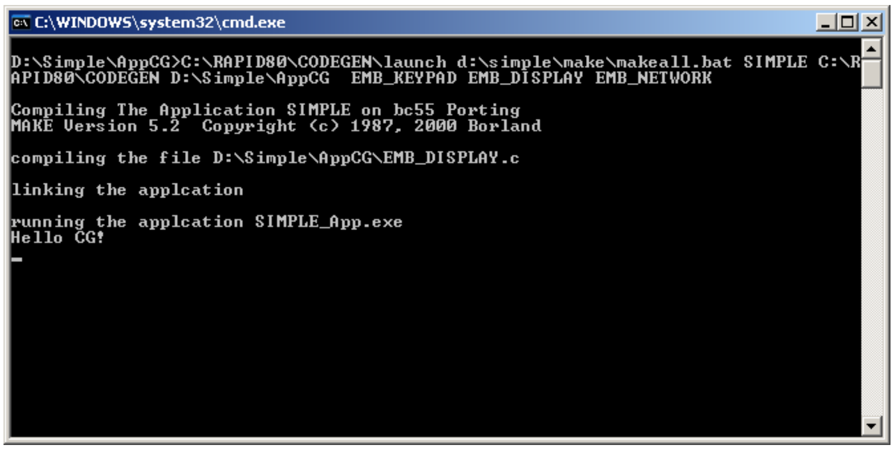
Listing 20-1: The generated *draw* function of EMB_DISPLAY

3. Add a *printf* call between the “RapidUserCode BEGIN” and “RapidUserCode END” remarks that prints the string argument Parm_str, as shown in Listing 20-2.

```
void EMB_DISPLAY_R15673_draw_ ( EMB_DISPLAY* udo,
                                const pchar  Parm_str)
  {
  /******************************************************************
   * subroutine draw: <String:str>
   * begin
   * Screen_Dsp.contents := <str> ;
   * end
   ******************************************************************/
/******** RapidUserCode BEGIN EMB_DISPLAY_R15673_draw_ ********/

     printf("%s\n", Parm_str);

/******** RapidUserCode END   EMB_DISPLAY_R15673_draw_ ********/
  }
```

Listing 20-2: The revised *draw* function of EMB_DISPLAY

4. In the AppCG subfolder, execute the batch file RunIt.bat. This will recompile the program, link it, and run it again. The result should be similar to Figure 20-7.



```
D:\Simple\AppCG>C:\RAPID80\CODEGEN\launch d:\simple\make\makeall.bat SIMPLE C:\R
APID80\CODEGEN D:\Simple\AppCG  EMB_KEYPAD EMB_DISPLAY EMB_NETWORK

Compiling The Application SIMPLE on bc55 Porting
MAKE Version 5.2  Copyright (c) 1987, 2000 Borland

compiling the file D:\Simple\AppCG\EMB_DISPLAY.c

linking the applcation

running the applcation SIMPLE_App.exe
Hello CG!
_
```

Figure 20-7: Simple running after integration

Note:
For the purpose of this example, the display's driver API was represented by the *printf* call.

Understanding the Execution Process

Figure 20-8 gives an overview of how the Simple program is executed:

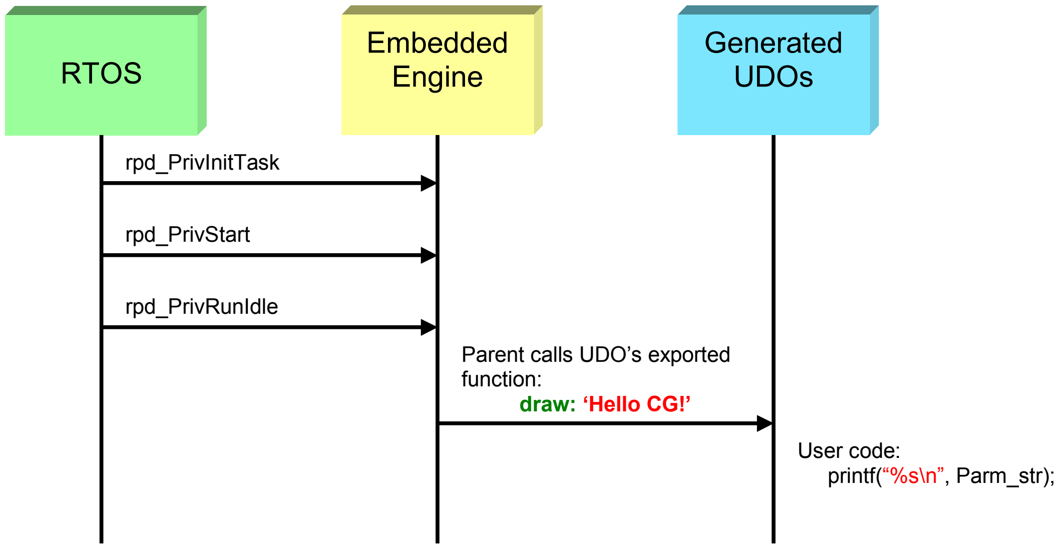


Figure 20-8: The execution process

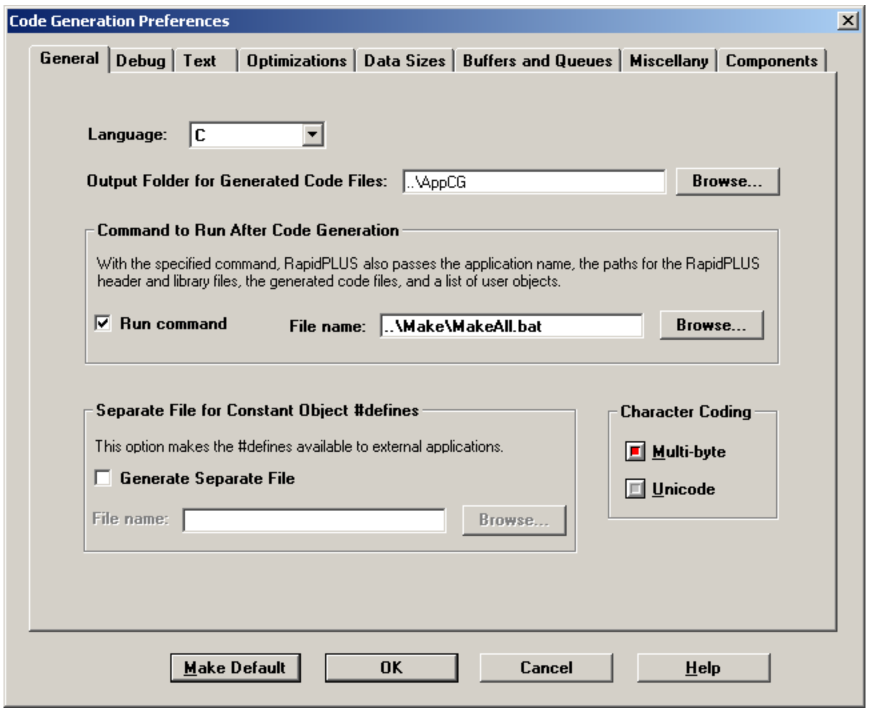
The three calls made from the RTOS to the embedded engine are part of the RapidPLUS embedded engine API. In general terms, they cause the engine to initialize, start, and cycle the state machine. We will discuss them in detail in Chapter 22, "The RapidPLUS API."

On the first cycle, the parent application calls the *draw* function of the display UDI, which in turn calls the hardware's driver API function, which in this case is ANSI-C's *printf* function.

The Code Generation Preferences

This section examines several of the preferences that you can set for the code generation process in RapidPLUS. The discussion will not go through all the settings. For further information please refer to the Online Help.

General Preferences



Language: C

Output Folder for Generated Code Files: ..\AppCG

Command to Run After Code Generation

With the specified command, RapidPLUS also passes the application name, the paths for the RapidPLUS header and library files, the generated code files, and a list of user objects.

☑ Run command File name: ..\Make\MakeAll.bat

Separate File for Constant Object #defines

This option makes the #defines available to external applications.

☐ Generate Separate File

File name:

Character Coding

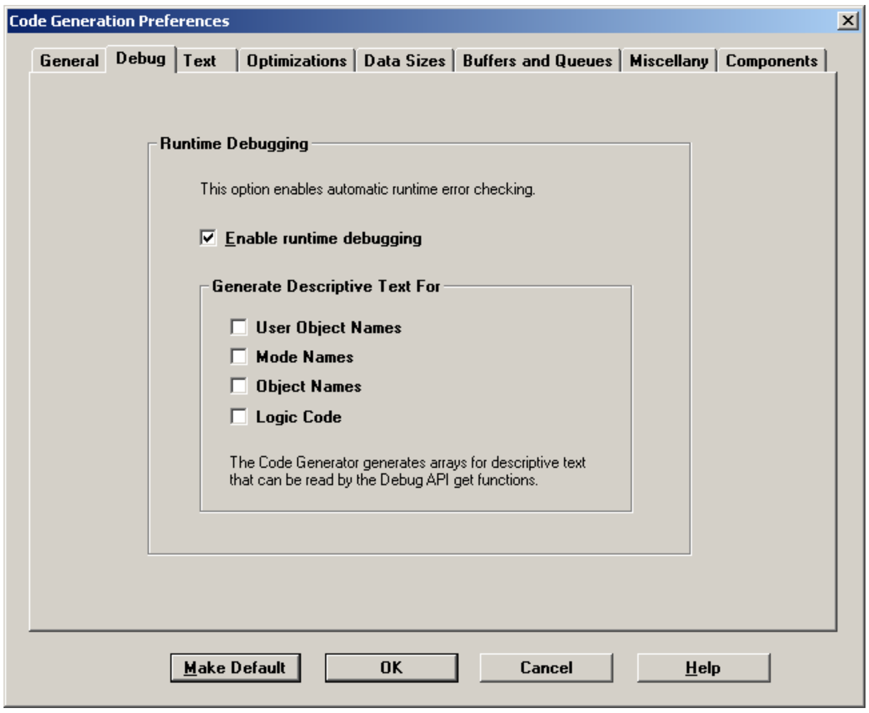
☑ Multi-byte

☐ Unicode

Figure 20-9: The General preferences tab

- **Language**—Defines the programming language to which the code will be generated. This can be either C or Java. The former is used for embedded systems, and the latter for Internet browser-based product simulations.
- **Output Folder for Generated Code Files**—The path of the folder in which the generate code files will be created.
- **Command to Run After Code Generation**—Name of a file to be executed immediately after the code is generated. Usually used for batched building of the application.

Debug Preferences



Runtime Debugging

This option enables automatic runtime error checking.

☑ Enable runtime debugging

Generate Descriptive Text For

☐ User Object Names
☐ Mode Names
☐ Object Names
☐ Logic Code

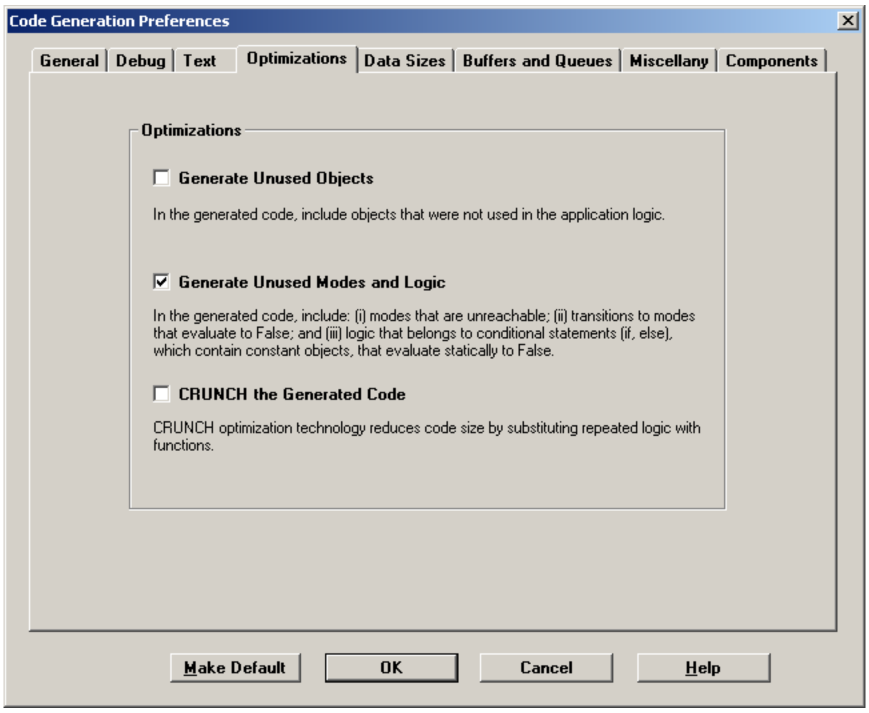
The Code Generator generates arrays for descriptive text that can be read by the Debug API get functions.

Figure 20-10: The Debug preferences tab

- **Enable runtime debugging**—This option only applies to C code generation. When marked, the code generator adds descriptive information in the form of constant strings to the generated code. This information can be read using RapidPLUS's special API functions for debugging.
  - *User Object Names*—When selected, the user object names are returned.
  - *Mode Names*—When selected, the actual mode names are returned.
  - *Object Names*—Not used.
  - *Logic Code*—When selected, the actual mode activity code and the actual transition code are returned.

Note:
If you disable runtime debugging, the application needs to be linked with a different RapidPLUS kernel module that doesn't support this feature. This is highly not recommended.

Optimization Preferences



Optimizations

☐ Generate Unused Objects

In the generated code, include objects that were not used in the application logic.

☑ Generate Unused Modes and Logic

In the generated code, include: (i) modes that are unreachable; (ii) transitions to modes that evaluate to False; and (iii) logic that belongs to conditional statements (if, else), which contain constant objects, that evaluate statically to False.

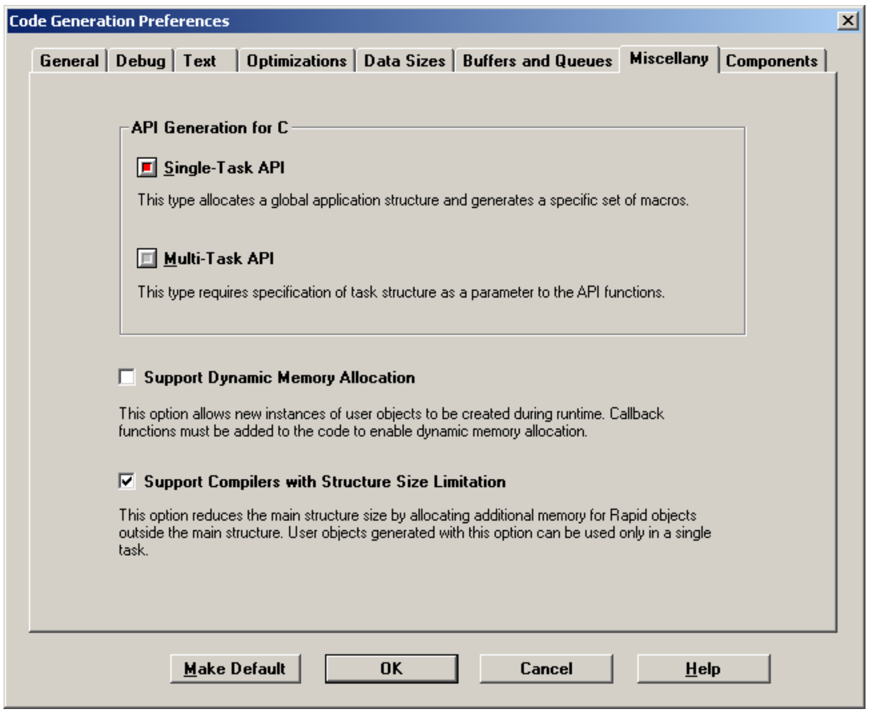
☐ CRUNCH the Generated Code

CRUNCH optimization technology reduces code size by substituting repeated logic with functions.

Figure 20-11: The Optimization preferences tab

- **Generate Unused Objects**—When selected, the code generator generates code even for objects that are not being used in the application, thus increasing the overall size of the code. By default, this option is not selected.
- **Generate Unused Modes and Logic**—When selected, the code generator generates code that handles modes and logic that were not actually used in the application. This increases the overall size of the code. By default, this option is selected.
- **CRUNCH the Generated Code**—When selected, a special optimization mechanism traverses the application logic and replaces repeated portions of logic with functions, thus reducing the overall size of the code. By default this option is not selected.

Miscellany Preferences



API Generation for C

[✓] Single-Task API

This type allocates a global application structure and generates a specific set of macros.

[ ] Multi-Task API

This type requires specification of task structure as a parameter to the API functions.

[ ] Support Dynamic Memory Allocation

This option allows new instances of user objects to be created during runtime. Callback functions must be added to the code to enable dynamic memory allocation.

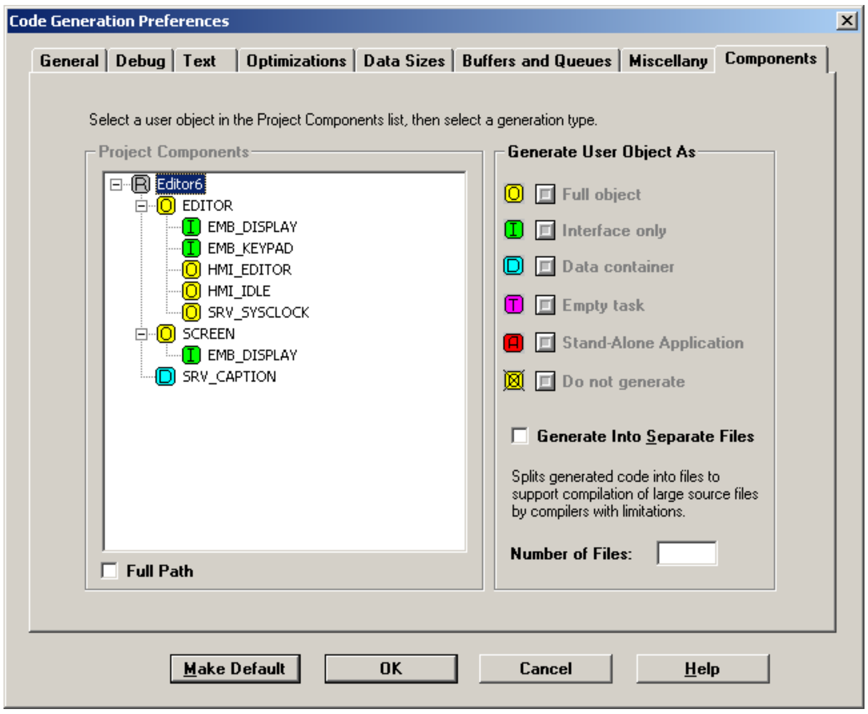
[✓] Support Compilers with Structure Size Limitation

This option reduces the main structure size by allocating additional memory for Rapid objects outside the main structure. User objects generated with this option can be used only in a single task.

Figure 20-12: The Miscellany preferences tab

- **API Generation for C**—RapidPLUS supports both single- and multi-task systems:
    - *Single-Task API*—The main application and all its UDOs are allocated in a single task.
    - *Multi-Task API*—Either several RapidPLUS applications need to run at the same time and share the RapidPLUS engine and generated code, or some UDOs work in a different task than the main application.
- **Support Dynamic Memory Allocation**—When selected, memory is allocated dynamically when new instances and objects are created at runtime. Callback functions for allocating and freeing memory must be added to the code. In addition, the application must be linked with a kernel module that supports DMA.
- **Support Compilers with Structure Size Limitations**—Reduces the main structure's size by allocating additional memory for RapidPLUS objects outside the main structure. Projects generated with this option can be used only in a single task.

Components Preferences


Code Generation Preferences

General | Debug | Text | Optimizations | Data Sizes | Buffers and Queues | Miscellany | Components

Select a user object in the Project Components list, then select a generation type.

Project Components

```
⊟ R Editor6
   ⊟ O EDITOR
        I EMB_DISPLAY
        I EMB_KEYPAD
        O HMI_EDITOR
        O HMI_IDLE
        O SRV_SYSCLOCK
   ⊟ O SCREEN
        I EMB_DISPLAY
     D SRV_CAPTION
```

☐ Full Path

Generate User Object As

- O ☐ Full object
- I ☐ Interface only
- D ☐ Data container
- T ☐ Empty task
- A ☐ Stand-Alone Application
- ☒ ☐ Do not generate

☐ Generate Into Separate Files

Splits generated code into files to support compilation of large source files by compilers with limitations.

Number of Files:

Figure 20-13: The Components preferences tab

- **Full object**—The UDO is generated in its entirety, including all of its interface, nested objects, and internal logic.
- **Interface only**—Used for UDIs Only the logic interface of the UDO is generated to code. The nested objects and internal logic (modes, transitions, etc.) are discarded.
- **Data container**—Used for UDDs. Only a message construct (union and structure within it) is generated. Internal logic and nested objects are totally discarded. The message fields are only accessible from the parent. Used to share complex information among several other UDOs.
- **Empty task**—A special case: sometimes other tasks that run on the target want to use RapidPLUS's GDO. In this case, the GDO is nested by a UDI that exports specific functions. The code generator generates two sets of files (headers and sources). One set is a simple UDI that is part of the RapidPLUS main task, while the other serves as an independent task, representing the GDO. The latter can be accessed by other tasks running on the target. In this case, no state machine (modes, transitions, etc.) is generated.
- **Standalone Application**—The entire UDO, along with its state machine, is generated as a completely separate task from the parent application. It can run on its own. Both sides have interfaces for inter-task communication and it is the integrator's responsibility to make sure these are integrated correctly.

Generated files

The code generation process generates source and header files for each UDO and for the parent application. The names of the generated files depend on the name of the object being generated, and in some cases they are affected by the generation method.
In this sense, if the name of a UDO is EMB_LED, the names of the generated files would be: emb_led.c and emb_led.h.
If the UDO was to be generated as a standalone application, the names of the generated files would be: temb_led.c and temb_led.h.

What can be found in the files?

The following tables summarize the difference in content between UDO and UDI generated source and header files:

	UDO	**UDI**
Header	• Local IDs • Type definitions of unions and structures • UDO structure	• Local IDs • Type definitions of unions and structures • UDO structure
Source	• State machine tables • Internal and exported functions • Activity code	• Exported functions • Functions for unions (activate, send, deactivate) • Functions for changed properties

Where does the user-code go?

In general, the only place in the source and header files that user-code can be present is between “RapidUserCode BEGIN” and “RapidUserCode END” remarks.
These remarks can be found in the main application and UDOs’ header files, and in both header and source files of UDIs. Any code outside these comments may interfere with proper work of the application, and will be removed if the code is re-generated. Code that appears between these remarks will remain after re-generation.

Chapter 21

Embedded Engine API

- Embedded Engine API
- Cycle Execution Sequence
- Timers API
- Integration Basis

Embedded Engine API

The RapidPLUS embedded engine is responsible for handling the state machine of the generated application. A set of API functions is available for use within the RapidPLUS task for controlling the embedded engine. These include function to:

- Initialize the engine, with or without dynamic memory allocation support.
- Start and stop the engine.
- Cycle the state machine.
- Update the timers being used by the application and nested UDOs.
- Dynamically allocate and free memory.

These functions are defined in a file called c_api.h that can be found in the codegen subfolder of the RapidPLUS installation folder on your local drive.

Note:
Since version 7.0, RapidPLUS supports multi-tasked applications. The functions for handling single-tasked applications were removed, and instead, if such an application is generated, a set of macros is generated to support single task API via the multi-task functions, which sit in the c_api.h file.

In this section we will go through the functions that get the engine ready to run the generated application.

Initializing the Engine

The first thing any RapidPLUS task does is to initialize the embedded engine. There are two functions for initializing the embedded engine:

- **RINT rpd_PrivInitTask()**—For no DMA support.
- **RINT rpd_PrivInitMallocTask()**—For DMA support.

Depending on your application requirements, you choose which one to use. If you need DMA, be sure to also generate the project accordingly.
Both of these functions expect a pointer to an error function as an argument. The DMA version expects two additional pointers to memory allocation and freeing functions.

DMA-Related Functions

The DMA initialization function registers the two functions for handling memory with the engine. The embedded engine calls these functions at runtime whenever memory needs to be allocated or freed.
The syntax of these functions is as follows:

- **void * rpd_Malloc(RINT memsize)**—For allocation.
- **void rpd_Free(void * memPtr)**—For freeing.

Starting the Engine

The next step is to start the engine and let it perform the first cycle of the state machine, so as to activate the default branches and execute the entry activities. This is done with a call to another API function:

- **RINT rpd_PrivStart()**

This function returns a value, which is referred to as the *moreToDo* value in RapidPLUS. This value will be discussed in further details later in this chapter.

Cycling the State Machine

The last step is to continuously cycle the state machine. We do so by calling yet another engine API function within a loop:

- **RINT rpd_PrivRunIdle()**

This function also returns the *moreToDo* value.

Cycle Execution Sequence

The embedded engine generally has three queues:

- User event queue.
- Logic event queue.
- Condition-Only Transitions And Mode Activities (COTAMA) queue.

On each cycle of the state machine, one event from the user event queue is handled. After that, all the pending events on the logic event queue are handled, and finally all the pending COTAMA on the COTAMA queue. During the cycle, additional events may be added to the queues, but these will only be handled on the next cycle.
Technically, both the logic event queue and the COTAMA queue are divided to output and input queues. On each cycle the entire output queue is processed, and new events or COTAMA are inserted at the end of the input queue.
At the end of each cycle, the status of the user event queue and of the input logic event and COTAMA queues is checked, and a value is returned. If all queues are empty, this value equals zero; otherwise its value indicates which queues are not empty. The name of this value is *moreToDo*.
The state machine cycles in response to either a rpd_PrivRunIdle call or a rpd_PrivUpdateTimer call. We will talk about the latter in the next section of this chapter.
Figure 21-1 illustrates the execution sequence of a state machine cycle.

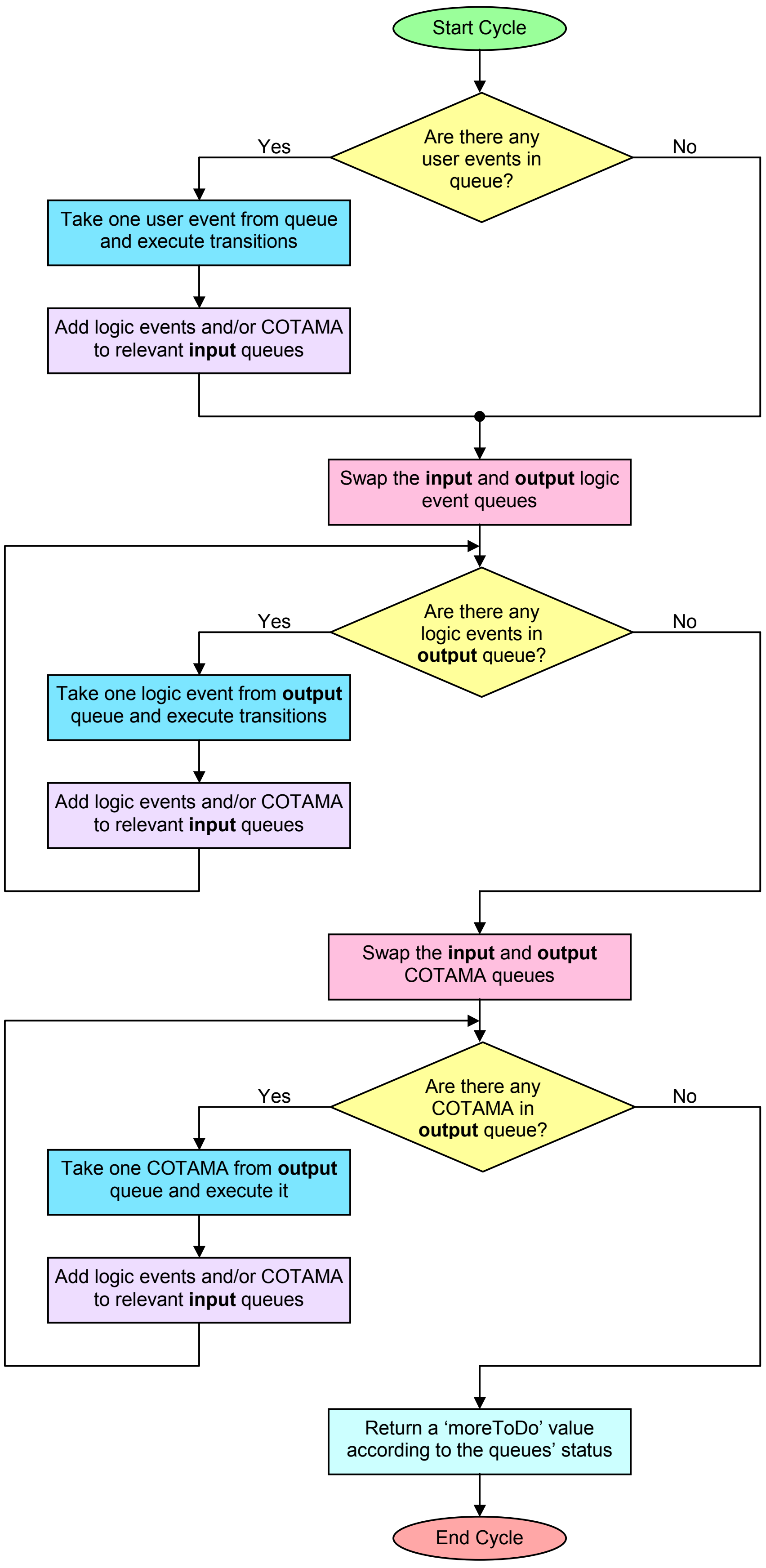

Start Cycle
Are there any user events in queue?
Yes
No
Take one user event from queue and execute transitions
Add logic events and/or COTAMA to relevant **input** queues
Swap the **input** and **output** logic event queues
Are there any logic events in **output** queue?
Yes
No
Take one logic event from **output** queue and execute transitions
Add logic events and/or COTAMA to relevant **input** queues
Swap the **input** and **output** COTAMA queues
Are there any COTAMA in **output** queue?
Yes
No
Take one COTAMA from **output** queue and execute it
Add logic events and/or COTAMA to relevant **input** queues
Return a 'moreToDo' value according to the queues' status
End Cycle

Figure 21-1: Cycle execution sequence

Timers API

The RapidPLUS application must be integrated to a timer service provided by the embedded system. Two types of APIs are available: **continuous timer update** and **update timer on request**. The type used is determined by the design of the embedded system.
The update timer on request API should be used for a system that implements sleep mode (for saving batteries), and will not be examined here. For more information on this method, please refer to the *"Generating Code for Embedded Systems"* manual.

Continuous Timer Update

If continuous timer update API is used, the timer service should send a message to the RapidPLUS task at a predefined frequency. This frequency can be defined based on performance issues. Frequency should be high enough for the timers defined in the application to work correctly, but not too high in order to avoid degradation of system performance.
The update of RapidPLUS's timers is done with a call to an API function:

- **RINT rpd_PrivUpdateTimer()**

The function expects a parameter that states the update interval. Once called, the function updates the counts of all timers in use within the application by the argument value, and executes a state machine cycle, which returns a *moreToDo* value. If this value is not zero, usually the developer chooses to give the state machine a few more cycles by calling rpd_PrivRunIdle() sequentially until the *moreToDo* value equals zero or a limit of cycles was excided.

Integration Basis

Framework for Integration Basis

Listing 21-1 gives a pseudo-C code for the main application.

```
void main(void)
{
    RINT rpd_moreToDo;
    int i, maxCycles = 10;

    /* Initialize the embedded engine in single-task mode without
       DMA support. */
    rpd_PrivInitTask (NULL);

    /* Start the engine and run the first cycle. */
    rpd_PrivStart();

    while (1)
    {
        /* Handle user events. */
        if (user messages arrived)
            Add appropriate user events to queue

        /* Update timers if necessary. */
        if (timeInterval passed)
            rpd_moreToDo = rpd_PrivUpdateTimer(timeInterval);

        /* Clear the engine's queues. */
        i = 0;
        while(rpd_moreToDo && i++<maxCycles)
            rpd_moreToDo = rpd_PrivRunIdle();
    }
}
```

Listing 21-1: Basis for usage of the embedded engine

app_api.c

The code presented in Listing 21-1 gives a basic framework for initializing and controlling the RapidPLUS embedded engine. This pseudo-C code may be suitable for small-scale projects, but for larger scale ones, you should take out the API calls from the main function and leave it as clean as possible.

In the codegen subfolder of the RapidPLUS installation folder on your local drive, you will find a subfolder named Interface. This subfolder contains some files that may aid you in integrating your project on your target platform. One of these files is named app_api.c (with a corresponding app_api.h header file). In this file you will find a set of wrapping functions for handling user input, the GDO, etc.

During the integration process, all custom changes to the application API, the API that operates the embedded engine, are made in this file. The main function should remain practically unchanged. Listing 21-2 shows one of the editable functions in the file, meant for handling input from a keypad.

```
int processKeyDown(int pressedKey)
{
    /* Writing feedback on the DOS console */
    printf("\n processKeyDown: %d", pressedKey);
    switch(pressedKey)
    {
        case KEY_1:
            break;
        case KEY_2:
            break;
        default: return 0;
    }

    /* Returning the moreToDo value, causing the main function to
       run Rapid cycles */
    return cEventQueueBit;
}
```

Listing 21-2: A function for processing a *KeyDown* event

In this example, you would change the cases and notify the RapidPLUS engine of the relevant event.

The Parts of a RapidPLUS Embedded Project

As you probably gathered by now, there is more to a RapidPLUS embedded project than just the generated code of your application. Figure 21-2 sums up the different components that take part in the project (excluding the GDO-related components).

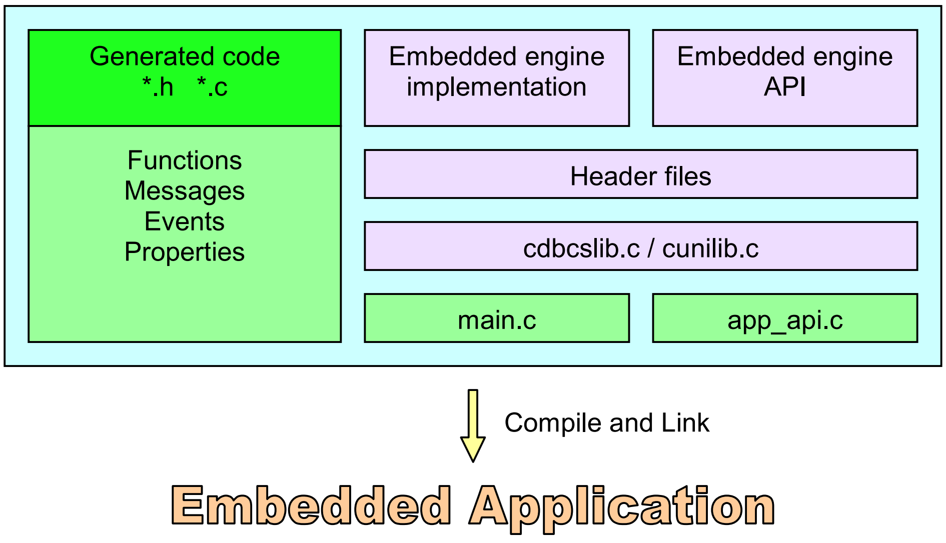


Figure 21-2: Participants in the embedded project

The embedded engine is provided as a compiled library suited for the target platform, in accordance with an agreement with e-SIM Ltd. The same goes for the GDO kernel (not discussed in this course). Several header files and customizable source files accompany the library for platform specific integration.

The files cdbcslib.c and cunilib.c (and another file named clib.c for old compilers) are provided to support double-byte character set and UNICODE encoding. These files should be customized according to project needs.
The rest of the components (along with the low-level implementation of the GDO with the platform, if a graphic display is used), can be customized by the integration team. This includes the generated code, the main function, and the application API (as mentioned earlier in this chapter).

Chapter 22

Integration of the Logic Interface

- Integration Overview
- Integrating an Event
- Integrating a Property Input
- Integrating a Message Input
- Updating Timers

Integration Overview

In Chapter 20, “Code Generation Process,” you generated a very simple application that drew a string of text on the display. To do so, you wrapped the display with a UDI called EMB_Display that exported a single function named *draw*. In the generated file emb_display.c, you added your own code to the “user code” section of the empty generated *draw* function, so that the application actually showed the text on the display (in this case the PC’s monitor).
This was the process of integrating an exported function. In the following sections of this chapter we will explore the integration of events, properties, and messages, all in the direction of UDI to application, which in RapidPLUS terms is considered the input direction. We will not discuss integration of properties and messages in the output direction.

Integrating an Event

Events always go in one direction: from the UDI to the parent application. This means that when an event happens in the embedded system, we need to relay it to the parent application.

Exercise 22-1: Integrating an event – Part 1

Name: Simple (Phase 2.1)
Description:
In this exercise you are going to add a pushbutton to the Simple application you started in Chapter 20. Pressing the pushbutton will cause an event that will toggle the parent application between two modes: ***Off*** and ***On***. Upon entering each mode, the parent application will draw the mode’s name on the display.
Instructions:

1. Create a new application. Save it as EMB_Keypad.udo in the RapidApp subfolder under the Simple project main folder.
2. Open the application file Simple.rpd.
3. Add the EMB_Keypad UDO to the application layout.
4. Switch to the UDO and adapt it according to the following instructions:
    - Add a pushbutton to the UDO’s layout.
    - Add an event named *KeyPressed* to the UDO’s logic interface.
    - Trigger the event when the pushbutton is pressed (internal action).
5. Switch back to the parent application.
6. Clear the entry activities of from the root mode.
7. Add two modes: ***Off*** and ***On***, and transitions between them.

8. The transitions should be triggered by the event coming from the EMB_Keypad UDO.
9. As an entry activity of each mode, draw the mode's name on the EMB_Display UDO, using its exported *draw* function.
10. Verify the changes you made in the simulation with the prototyper.
11. If all runs according to requirements, set the EMB_Keypad UDO to be generated as a UDI.
12. Save and generate all the code.

Adding the Integration Code

Although the code generator regenerates all the files, it keeps anything that the user added between the "RapidUserCode BEGIN" and "RapidUserCode END" remarks. Anything you added outside these remarks is removed. This means you do not need to worry about the *draw* function. What you do need to add is integration code for the new event.

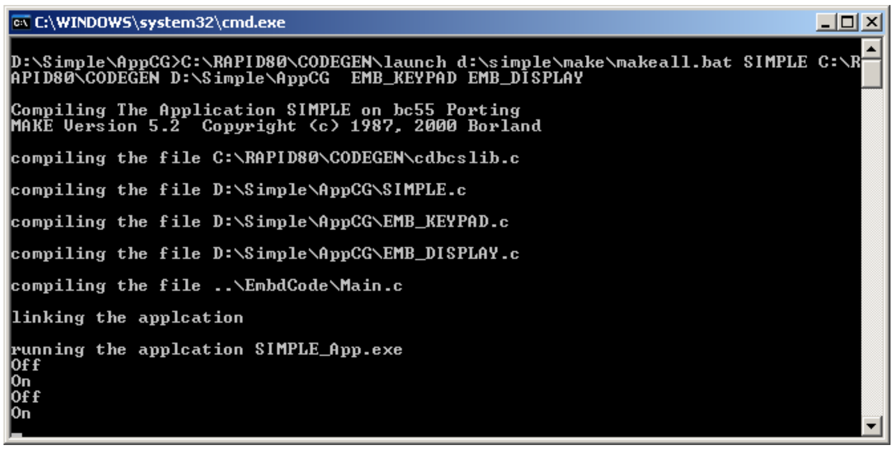
Exercise 22-2: Integrating an event – Part 2

Name: Simple (Phase 2.2)
Description:
In this part of the exercise you will add integration code for the new pushbutton and event you added to the Simple application in Exercise 22-1.
Instructions:

1. Open the file simple.h, in the AppCG subfolder under the Simple project folder.
2. Scroll down until you reach a section marked "Concrete Object Functions." Under this section you will find several macros. All of the exported events, messages, and properties of all UDIs used in the application cause several macros to be generated in this section.
3. Find the macro defined under the comment "Trigger the KeyPressed event for the EMB__KEYPAD object." Its name will be something like: R9394_EMB__KEYPAD_KeyPressed().
4. Copy the macro's name and close the file.
5. Open the file main.c, in the EmbdCode subfolder under the Simple project folder.
6. Edit the main function so it resembles Listing 22-1.
7. In the AppCG subfolder, execute the RunIt.bat file to recompile, link, and execute the program.
8. Pressing any key on the keyboard should cause the application to toggle between the ***<u>Off</u>*** and ***On*** modes. Figure 22-1 shows the running application.

```
/* Variable for keyboard input */
char pressedKey = 0;

/* Variable for system tick value reference */
unsigned long lSystemLastTick;

void main(void)
{
    RINT rpd_moreToDo;
    int i, maxCycles = 10;

    /* Initialize the embedded engine in single-task mode without
       DMA support. */
    rpd_PrivInitTask (NULL);

    /* Start the engine and run the first cycle. */
    rpd_PrivStart();

    while (1)
    {
        /* Handle user events */
        if (kbhit())
        {
            pressedKey = getch();

            R9394_EMB__KEYPAD_KeyPressed();

            rpd_moreToDo = rpd_PrivRunIdle();
        }

        /* Update timers if necessary. */
        if ( clock()> lSystemLastTick)
        {
            rpd_moreToDo = rpd_PrivUpdateTimer(10);
            lSystemLastTick = clock();
        }

        /* Clear the engine's queues. */
        i = 0;
        while (rpd_moreToDo && i++<maxCycles)
            rpd_moreToDo = rpd_PrivRunIdle();
    }
}
```

Listing 22-1: The main function after integrating the event



```
D:\Simple\AppCG>C:\RAPID80\CODEGEN\launch d:\simple\make\makeall.bat SIMPLE C:\R
APID80\CODEGEN D:\Simple\AppCG  EMB_KEYPAD EMB_DISPLAY

Compiling The Application SIMPLE on bc55 Porting
MAKE Version 5.2  Copyright (c) 1987, 2000 Borland

compiling the file C:\RAPID80\CODEGEN\cdbcslib.c

compiling the file D:\Simple\AppCG\SIMPLE.c

compiling the file D:\Simple\AppCG\EMB_KEYPAD.c

compiling the file D:\Simple\AppCG\EMB_DISPLAY.c

compiling the file ..\EmbdCode\Main.c

linking the applcation

running the applcation SIMPLE_App.exe
Off
On
Off
On
```

Figure 22-1: Simple running after event integration

Integrating a Property Input

A property can be changed either by the UDO or the parent application. When it comes to UDIs, there's usually no reason to change the property from the parent application. We will therefore focus the discussion on changes in the input direction, i.e., from the UDI to the application.

Exercise 22-3: Integrating a property input – Part 1
Name: Simple (Phase 3.1)
Description:
In this part of the exercise you will add a new pushbutton and a property to the Simple application. The property will hold the code of the last pushbutton that was pressed. This value will be used in conditions within the parent application to make the transitions between the ***Off*** and ***On*** modes, and for triggering an internal action within the mode ***On***.
Instructions:

1. Open the application file Simple.rpd, in the RapidApp subfolder under the Simple project folder.
2. Switch to the Keypad UDO and adapt it according to the following instructions:
   - Add a new pushbutton to the UDO.
   - Add an integer property named *KeyCode* to the UDO's logic interface, and set its initial value to 0.
   - Set the value of the property to be 1 if the on/off pushbutton was pressed and 2 if the new pushbutton was pressed.
3. Switch back to the parent application.
4. Add conditions to the triggers of the transitions between modes ***Off*** and ***On*** that check if the on/off pushbutton was pressed.

5. When ***On***, a press on the new pushbutton causes the text on the display to change to a “Hello CG!” message. Use an internal transition with a compound trigger for that purpose.
6. Test your application in the prototyper.
7. If all is well, regenerate the code.

Adding the Integration Code

The code generator added two macros to the “Concrete Object Functions” section of the Simple.h file. These macros are used for setting and getting the value of the property. Each property you add to the logic interface of any UDI in the application adds two such macros.

The macros serve in the context of the UDI, since the UDI is what needs to be integrated. This means that the *set* macro is used when the UDI changes the value of the property, and the *get* macro is used when the UDI needs to retrieve the value of the property. The application’s side is already taken care of by the code generator.

Exercise 22-4: Integrating a property input – Part 2

Name: Simple (Phase 3.2)

Description:

In this part of the exercise you will add integration code for the new pushbutton and property you added to the Simple application in Exercise 22-3.

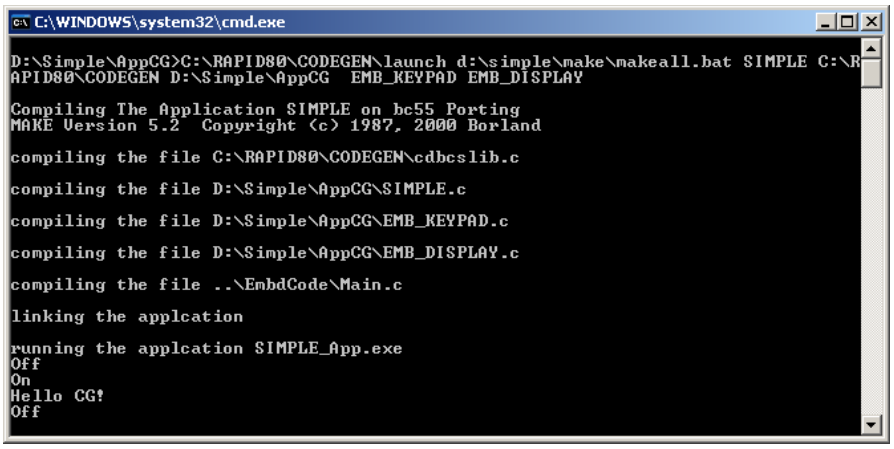
Instructions:

1. Open the file simple.h, in the AppCG subfolder under the Simple project folder.
2. Scroll down until you reach a section marked “Concrete Object Functions.”
3. Find the macro defined under the comment “Set the Prop_R5997_KeyCode__Int property for the EMB__KEYPAD object”. The name of the macro should be something like: R4348_EMB__KEYPAD_set_KeyCode_Int(value).
4. Copy the macro’s name and close the file.
5. Open the file main.c, in the EmbdCode subfolder under the Simple project folder.
6. Edit the user event handling section so to resemble Listing 22-2. The code now reflects the distinction between two buttons by setting the property’s value according to the key that was pressed.
7. In the AppCG subfolder, execute the RunIt.bat file to recompile, link, and execute the program.

8. Pressing the 1 key will toggle the application between the ***Off*** and ***On*** modes. While in ***On*** mode, pressing the 2 key will cause the "Hello CG1" message to be displayed. Pressing any other key will have no effect. Figure 22-2 shows the running application.

```
/* Handle user events */
if (kbhit())
{
    pressedKey = getch();

    switch (pressedKey)
    {
    case '1':
        R4348_EMB__KEYPAD_set_KeyCode_Int(1);
        R9394_EMB__KEYPAD_KeyPressed();
        break;
    case '2':
        R4348_EMB__KEYPAD_set_KeyCode_Int(2);
        R9394_EMB__KEYPAD_KeyPressed();
        break;
    };

    rpd_moreToDo = rpd_PrivRunIdle();
}
```

Listing 22-2: The user event handling section after integrating the property input.



```
D:\Simple\AppCG>C:\RAPID80\CODEGEN\launch d:\simple\make\makeall.bat SIMPLE C:\R
APID80\CODEGEN D:\Simple\AppCG  EMB_KEYPAD EMB_DISPLAY

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compiling the file C:\RAPID80\CODEGEN\cdbcslib.c

compiling the file D:\Simple\AppCG\SIMPLE.c

compiling the file D:\Simple\AppCG\EMB_KEYPAD.c

compiling the file D:\Simple\AppCG\EMB_DISPLAY.c

compiling the file ..\EmbdCode\Main.c

linking the applcation

running the applcation SIMPLE_App.exe
Off
On
Hello CG!
Off
```

Figure 22-2: Simple running after property input integration

Integrating a Message Input

As with property assignments, message sending can be done in either direction. With UDIs, messages are usually sent from the UDI to the parent application, i.e., in the input direction. We will therefore explore only this direction.

Exercise 22-5: Integrating a message input – Part 1
Name: Simple (Phase 4.1)
Description:
In this part of the exercise you will add a new UDI to represent a simple network connection. The network will send text messages to the parent application. For the purpose of this exercise, a message will be sent every time a pushbutton is pressed.
Instructions:

1. Create a new application and save it as EMB_Network.udo in the RapidApp subfolder under the Simple project main folder.
2. Open the application file Simple.rpd.
3. Add the EMB_Network UDO to the application.
4. Switch to the EMB_Network UDO and adapt it according to the following instructions:
   - Add a pushbutton to the UDO.
   - Add a message to the UDO's logic interface, comprising a single structure named Body, with one string field named Text_Str. Name the containing union Notification_msg.
   - Whenever the pushbutton is pressed, prepare the message and send it with "You have new mail!" as the field's value.
5. Switch back to the parent application.
6. Add a new internal action to the ***On*** mode that is triggered by an incoming message from the EMB_Network UDO. The action should draw the incoming text on the EMB_Display.
7. Test the changes in the prototyper.
8. Generate the code correctly (EMB_Network should be a UDI).

Adding the Integration Code

The code generator added a macro for sending the message to the "Concrete Object Functions" section in the Simple.h file. The macro expects a pointer to a message and the message's size.
As with the macros added for handling property updates, the macro for sending the message is used in the context of the UDI. This means that calling it is equivalent to sending the message from the UDI to the parent application in RapidPLUS.

Exercise 22-6: Integrating a message input – Part 2

Name: Simple (Phase 4.2)

Description:

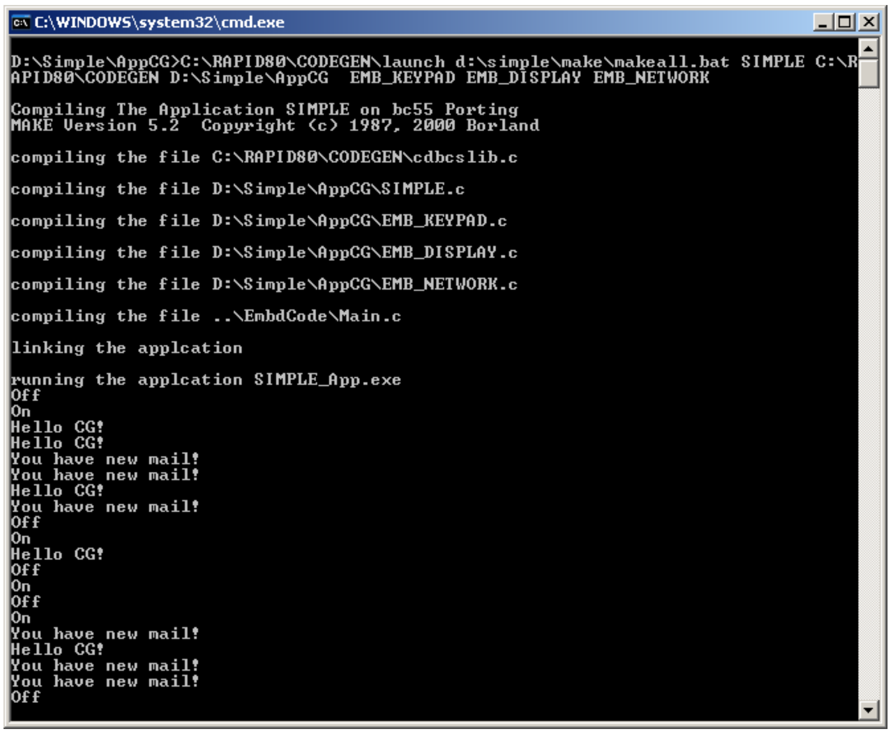
In this part of the exercise you will add integration code for the new UDI you added to the Simple application in Exercise 22-5.

Instructions:

1. Open the file emb_network.h, in the AppCG subfolder under the Simple project folder.
2. Scroll to the "Structures" section and find the definition of the message body structure. The name of the type definition should be something like ILSTR_EMB_NETWORK_R7222_Body.
3. Copy the name of the type definition.
4. In the file main.c, in the EmbdCode subfolder under the Simple project folder, add a local variable of the message type to the main function.
5. Open the file Simple.h and scroll to the "Concrete Object Functions" section.
6. Find and copy the name of the macro for sending a message. It should be under the comment "Send the Notification_Msg.Body structure to the EMB__NETWORK object".
7. Edit the user event handling section so it resembles Listing 22-3. The code now reflects the process of preparing the message and sending it in response to the key press. Note that the name of the field containing the actual message text may be different. The field is defined in the emb_network.h file, so make sure you use the correct name.
8. In the AppCG subfolder, execute the RunIt.bat file to recompile, link, and execute the program.
9. In ***On*** mode, pressing the 3 key will cause the network to send a message to the application, which in turn will draw the message on the display. Figure 22-3 shows the running application.

```
void main(void)
{
    RINT rpd_moreToDo;
    int i, maxCycles = 10;
    ILSTR_EMB_NETWORK_R7222_Body myLocalMessage;

    /* Initialize the embedded engine in single-task mode without
       DMA support. */
    rpd_PrivInitTask (NULL);

    /* Start the engine and run the first cycle. */
    rpd_PrivStart();

    while (1)
    {
        /* Handle user events */
        if (kbhit())
        {
            pressedKey = getch();

            switch (pressedKey)
            {
            case '1':
                R4348_EMB__KEYPAD_set_KeyCode_Int(1);
                R9394_EMB__KEYPAD_KeyPressed();
                break;
            case '2':
                R4348_EMB__KEYPAD_set_KeyCode_Int(2);
                R9394_EMB__KEYPAD_KeyPressed();
                break;
            case '3':
                strcpy(myLocalMessage.cSF_R7572_Text__Str,
                    "You have new mail!");
                R13205_EMB__NETWORK_send_Notification__Msg_Body
                    (&myLocalMessage, sizeof(myLocalMessage));
                break;
            };

            rpd_moreToDo = rpd_PrivRunIdle();
        }

        /* Update timers if necessary. */
        if ( clock()> lSystemLastTick)
        {
            rpd_moreToDo = rpd_PrivUpdateTimer(10);
            lSystemLastTick = clock();
        }

        /* Clear the engine's queues. */
        i = 0;
        while (rpd_moreToDo && i++<maxCycles)
            rpd_moreToDo = rpd_PrivRunIdle();
    }
}
```

Listing 22-3: The main function after integrating the message input.



```
D:\Simple\AppCG>C:\RAPID80\CODEGEN\launch d:\simple\make\makeall.bat SIMPLE C:\R
APID80\CODEGEN D:\Simple\AppCG  EMB_KEYPAD EMB_DISPLAY EMB_NETWORK

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compiling the file C:\RAPID80\CODEGEN\cdbcslib.c

compiling the file D:\Simple\AppCG\SIMPLE.c

compiling the file D:\Simple\AppCG\EMB_KEYPAD.c

compiling the file D:\Simple\AppCG\EMB_DISPLAY.c

compiling the file D:\Simple\AppCG\EMB_NETWORK.c

compiling the file ..\EmbdCode\Main.c

linking the applcation

running the applcation SIMPLE_App.exe
Off
On
Hello CG!
Hello CG!
You have new mail!
You have new mail!
Hello CG!
You have new mail!
Off
On
Hello CG!
Off
On
Off
On
You have new mail!
Hello CG!
You have new mail!
You have new mail!
Off
```

Figure 22-3: Simple running after message input integration

Updating Timers

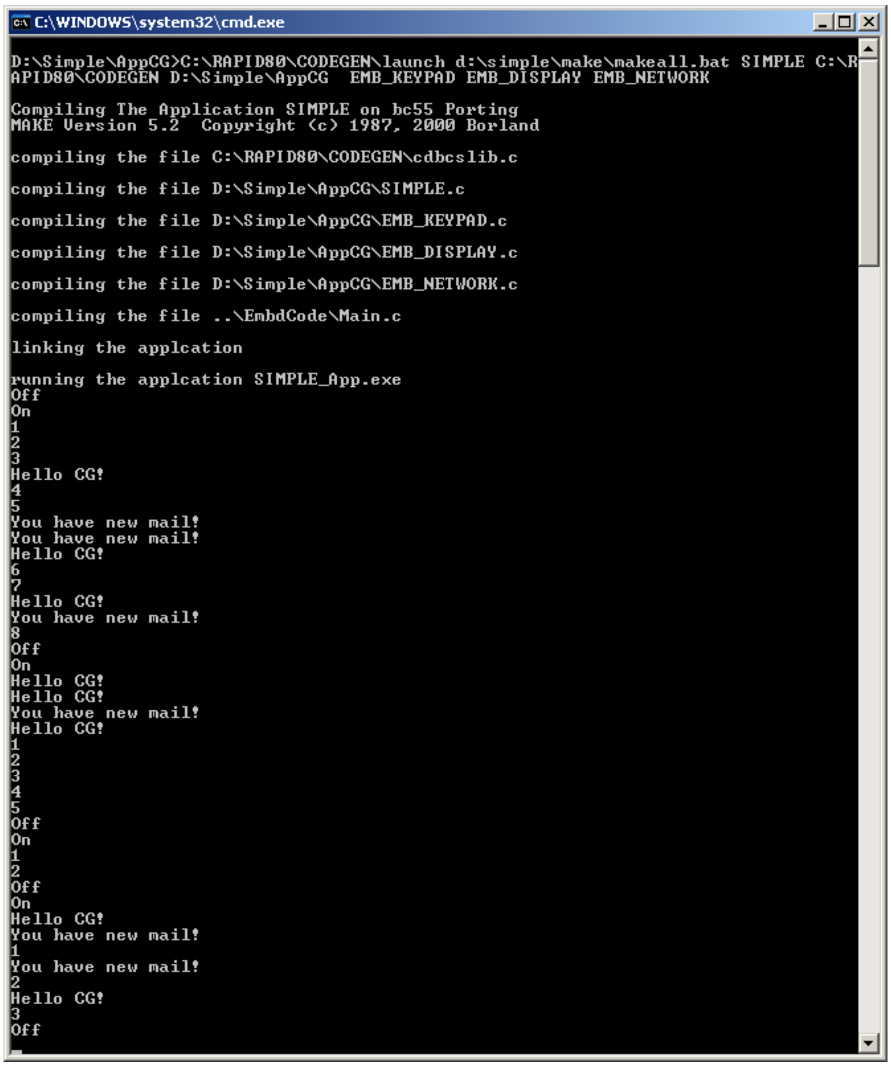
The main.c file you worked on in the last few exercises already takes care of updating RapidPLUS's timers in a continuous fashion. This is suitable for the purpose of this course. You may need to choose a different interval, or even use an on request update method on your target system.
You only need to tell RapidPLUS's embedded engine to update the timers in one place in your code. The engine takes care of updating all of the timers used in the application and nested UDOs.

Exercise 22-7: Updating the timers

Name: Simple (Phase 5)
Description:
In this exercise you will add a timer and an integer data object to the parent application. The timer will repeatedly count a period of 1 second while the application is in ***On*** mode. On every tick, the integer will be increased and its value will be drawn on the display.
Instructions:

1. Open the application Simple.rpd in the RapidApp subfolder under the Simple project folder.
2. Add a 1-second timer and an integer data object to the application.
3. Set the integer to 0 on every entry to ***On*** mode.

4. Make the timer start counting repeatedly upon entering ***On*** mode and stop it upon exiting the mode.
5. On every tick of the timer, increase the value of the integer by 1 and draw it on the display.
6. Generate the application. There's no need to perform any special integration this time. Figure 22-4 shows the running application.



```
D:\Simple\AppCG>C:\RAPID80\CODEGEN\launch d:\simple\make\makeall.bat SIMPLE C:\R
APID80\CODEGEN D:\Simple\AppCG  EMB_KEYPAD EMB_DISPLAY EMB_NETWORK

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compiling the file C:\RAPID80\CODEGEN\cdbcslib.c

compiling the file D:\Simple\AppCG\SIMPLE.c

compiling the file D:\Simple\AppCG\EMB_KEYPAD.c

compiling the file D:\Simple\AppCG\EMB_DISPLAY.c

compiling the file D:\Simple\AppCG\EMB_NETWORK.c

compiling the file ..\EmbdCode\Main.c

linking the applcation

running the applcation SIMPLE_App.exe
Off
On
1
2
3
Hello CG!
4
5
You have new mail!
You have new mail!
Hello CG!
6
7
Hello CG!
You have new mail!
8
Off
On
Hello CG!
Hello CG!
You have new mail!
Hello CG!
1
2
3
4
5
Off
On
1
2
Off
On
Hello CG!
You have new mail!
1
You have new mail!
2
Hello CG!
3
Off
```

Figure 22-4: Simple using a timer

Day 5 Summary

- Day 5 Recap
- Summary Exercise

Day 5 Recap

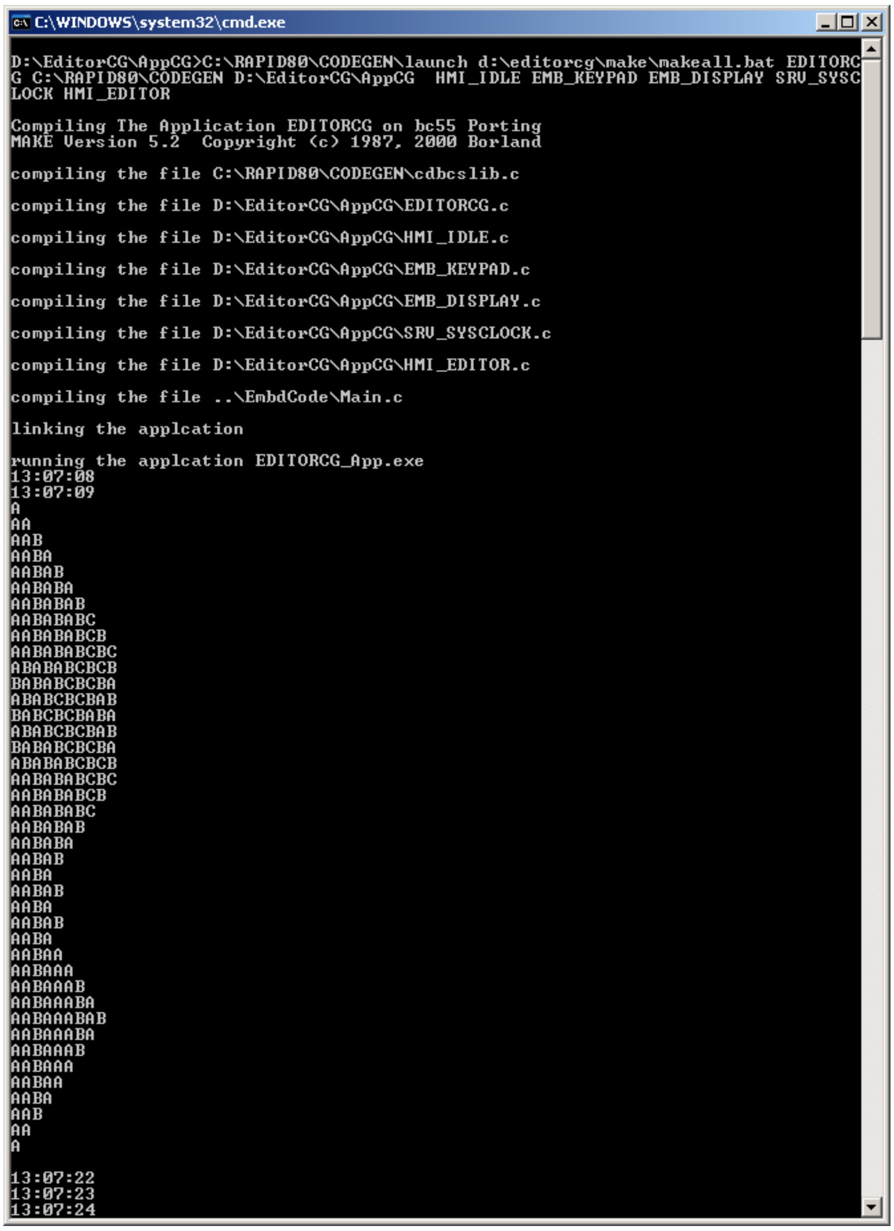
Day 5 gave an introduction to RapidPLUS code generation and integration for embedded systems.
Chapter 19 presented the perspective of the target platform with regards to the place of the RapidPLUS application among the different tasks that runs on it. It illustrated in a schematic fashion the process a RapidPLUS simulation undergoes when generated into code.
Chapter 20 surveyed the process of generating code from the RapidPLUS simulation and inspected the different preference settings for the generation process. The chapter concluded with the generation of a simple application and an integration of one exported function.
Chapter 21 explored the embedded engine API (often referred to as the application API). It also presented the execution sequence of a RapidPLUS embedded state machine cycle and provided a pseudo-C framework for integration that was used in the exercises in Chapter 22.
Chapter 22 focused on integrating events, properties, and messages to complete the arsenal of logic interfaces (functions were discussed in Chapter 20). It also showed that RapidPLUS takes care of all the timers used in the application and that the integrator only needs to deal with the update as a whole.

Summary Exercise

Exercise: Integration summary
Name: EditorCG
Description:
In this exercise you will generate the code of an early version of the editor application and integrate it to the DOS environment.
Instructions:

1. Copy Borland_5.5_Compile_Environment_Template_Dos to a local folder, and rename it EditorCG. This will be the project's environment.
2. Open the file main.c found in the EmbdCode subfolder and edit the first *#include* statement to include the file EditorCG.h.
3. Copy the following files from your exercises folder to the RapidApp subfolder under the EditorCG project folder.
   - Editor2.rpd
   - HMI_Idle.udo
   - HMI_Editor.udo
   - SRV_SysClock.udo
   - EMB_Keypad.udo
   - EMB_Display.udo

4. Open the application Editor2.rpd and save it as EditorCG.rpd. You can delete the old file Editor2.rpd as we won't use it.
5. Set the preferences for code generation, save the application, and generate the code for the application.
6. Integrate the two UDIs properly.
7. Compile, link, and run the application. Figure S5-1 shows the result.



```
C:\WINDOWS\system32\cmd.exe

D:\EditorCG\AppCG>C:\RAPID80\CODEGEN\launch d:\editorcg\make\makeall.bat EDITORC
G C:\RAPID80\CODEGEN D:\EditorCG\AppCG  HMI_IDLE EMB_KEYPAD EMB_DISPLAY SRV_SYSC
LOCK HMI_EDITOR

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compiling the file C:\RAPID80\CODEGEN\cdbcslib.c

compiling the file D:\EditorCG\AppCG\EDITORCG.c

compiling the file D:\EditorCG\AppCG\HMI_IDLE.c

compiling the file D:\EditorCG\AppCG\EMB_KEYPAD.c

compiling the file D:\EditorCG\AppCG\EMB_DISPLAY.c

compiling the file D:\EditorCG\AppCG\SRV_SYSCLOCK.c

compiling the file D:\EditorCG\AppCG\HMI_EDITOR.c

compiling the file ..\EmbdCode\Main.c

linking the applcation

running the applcation EDITORCG_App.exe
13:07:08
13:07:09
A
AA
AAB
AABA
AABAB
AABABA
AABABAB
AABABABC
AABABABCB
AABABABCBC
ABABABCBCB
BABABCBCBA
ABABCBCBAB
BABCBCBABA
ABABCBCBAB
BABABCBCBA
ABABABCBCB
AABABABCBC
AABABABCB
AABABABC
AABABAB
AABABA
AABAB
AABA
AABAB
AABA
AABAB
AABA
AABAA
AABAAA
AABAAAB
AABAAABA
AABAAABAB
AABAAABA
AABAAAB
AABAAA
AABAA
AABA
AAB
AA
A

13:07:22
13:07:23
13:07:24
```

Figure S5-1: EditorCG running in DOS

RapidPLUS

Appendixes

- Appendix A: The RapidPLUS User Interface
- Appendix B: Answers to Course Questions

Appendix A:

The RapidPLUS User Interface

- Desktop Arrangement
- Mode Tree
- Logic Editor
- Logic Palette
- State Chart
- Prototyper
- Adding Notes
- Copy & Paste

Desktop Arrangement

RapidPLUS is a windows-intensive application. A “clean” desktop arrangement can save time and prevent frustration. You do not need to minimize or close any window; instead you should use the Application Manager toolbar (the main window) to navigate between the different tools. Figure A-1 shows the recommended arrangement.

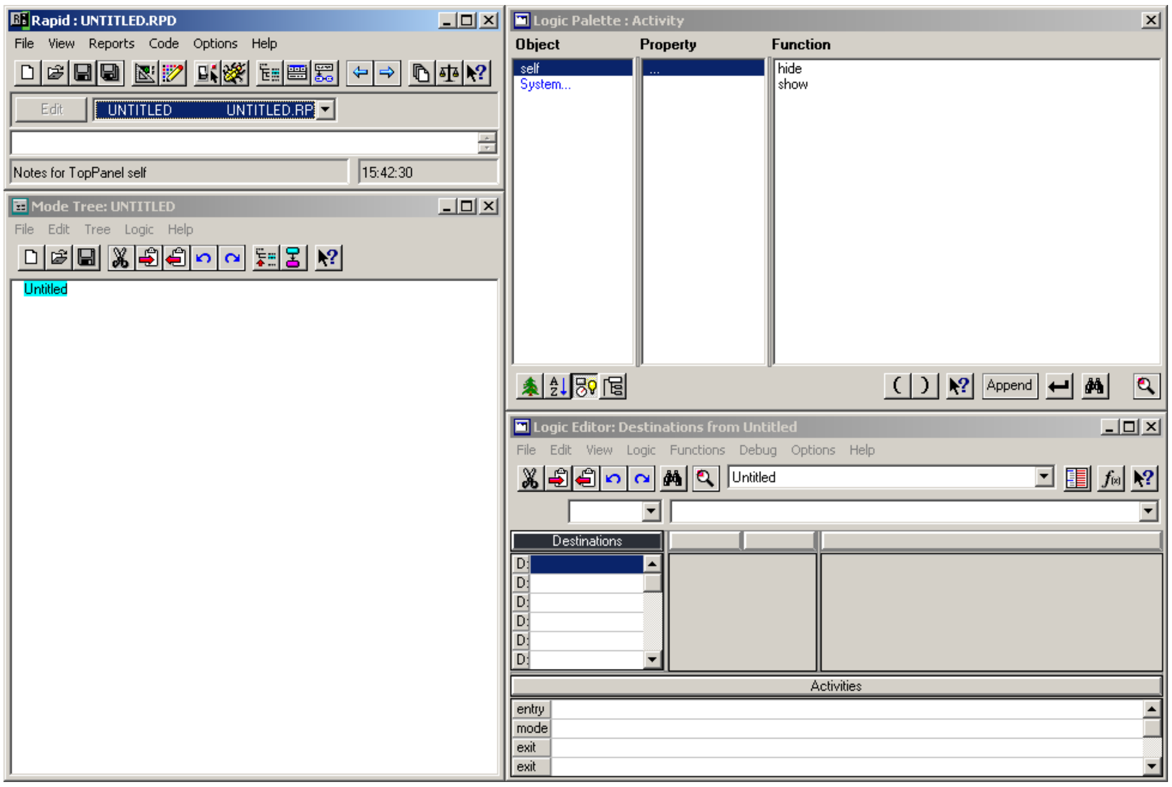


Figure A-1: The recommended desktop arrangement of RapidPLUS

The Application Manager is in the top-left corner. Beneath it is the Mode Tree tool. On the right side are tools such as the Logic Editor and Palette, the Object Layout and Editor, the State Chart tool, etc. Figure A-1 shows the Logic Editor and Palette.
Once you have arranged the different windows to your liking, you can save their configuration by selecting “Save Settings Now” from the Options menu. The “Save Settings on Exit” option causes any changes you made to the arrangement to be saved when you exit RapidPLUS. This may become a hassle and therefore is not recommended for use.
You can also change the font RapidPLUS uses to display text (menus, titles, mode names, etc.) by selecting Change Font from the Fonts submenu of the Options menu, and then selecting the desired font and its size.

Mode Tree

You can access the Mode Tree's commands through its popup menu. To open the menu, right-click the background of the Mode Tree. Figure A-2 shows the Mode Tree's popup menu.

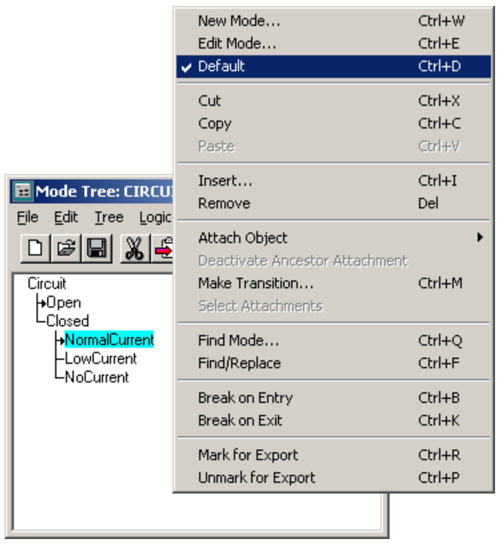


Figure A-2: The Mode Tree's popup menu

Useful Commands

- **Default**—Designate any exclusive mode in a branch as the default under the parent. According to the state machine rules, when you select a mode as the default, if another mode was previously designated as default, it becomes non-default, since only one mode can be default.

  You can also use this option to remove the default mode in the branch, in which case RapidPLUS will determine which mode to activate dynamically according to the logic (conditions). Use this option with caution as if more than one or less than one mode can become active, a runtime error will occur.

- **Cut**—An operation that cuts an entire branch under the selected mode and copies it to the clipboard. Any transitions made from and to the branch, along with their associated logic (triggers and actions), will be completely lost.

- **Copy**—Copies the entire branch under the selected mode. All the transitions to and from the branch and their associated logic are copied as well. You can also use Ctrl+Drag to perform the copying and pasting process.

  Copied branches can be pasted across applications, together with the objects used in their logic.

- **Insert**—Inserts a new generation of modes between the selected mode and its children.

- **Remove**—Deletes the selected mode without deleting its children. The children of the deleted mode become children of its parent. This operation can only be performed if the resulting tree is compliant with the state machine rules.

- **Find Mode**—Search a mode by its name.
- **Find/Replace**—Find and replace logic.
- **Break on Entry/Exit**—Commands for the debugger.

Logic Editor

The logic editor holds all the logic of the application. The logic can be manipulated in various forms. Figure A-3 shows the Logic Editor.

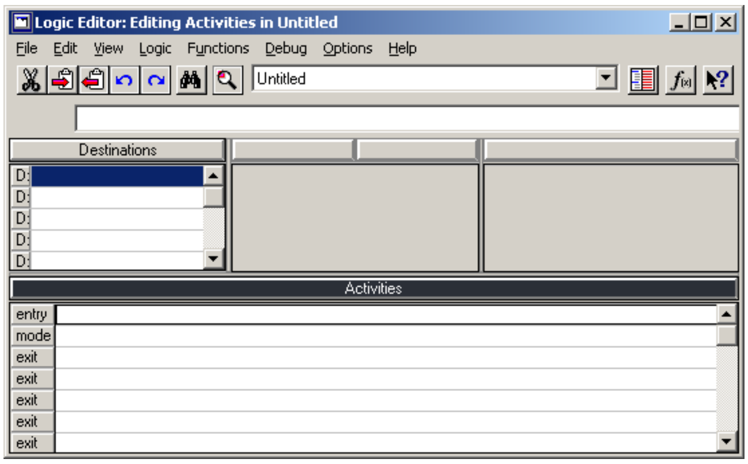


Figure A-3: The Logic Editor

Using the Logic Editor

Destinations and Triggers

The Logic Editor displays the logic for one mode at a time. That mode's name appears in the Mode List just beneath the menu. Transitions from the edited mode are listed by their destination in the Destinations section of the editor. You can see the triggers for a transition by focusing on the specific destination. The triggers will be listed in the center column of the window, under the Event/Condition title.
When you cut or copy a destination, the triggers attached to it, their respective actions, and any object that is used in the logic are included in the action. When you copy a trigger, its actions and any object that is used in the logic are included.

Editing Activities

You see the mode's activities in the Activities column. The "entry", "mode," and "exit" titles represent the time frames in which the activities take place. You can add additional lines of activities by hitting the Enter or Insert keys.
You can change an activity's type by right-clicking the activity and selecting the required type from the popup menu, or simply by dragging the activity to a line of the desired type. Dragging is done in three steps:

1. Select the activity (or several activities) you wish to drag.
2. Move the cursor over the gray separation line between the rows until it changes from a cross to an arrow.
3. Click and drag your selection to the required time frame.

If you wish to copy a set of activities to a different mode, you can copy the activities from one mode and paste them in another. However, simply pasting the activities in the new mode will not retain the activity type, but instead paste all the activities as the same type. In order to keep the original time frame specification for each activity, use the ‘Paste by Type’ option from the popup menu.

General Tips For Using the Logic Editor

You can change the proportions of the different sections by dragging the horizontal and vertical borders between them. You can also zoom in and out of one section by double-clicking a line of logic within it.
Before you can define new logic, make sure that the focus is on a blank line. If necessary, create additional lines using the Enter or Insert keys. Whenever the focus is changed, RapidPLUS performs a syntax check on the line of logic that lost the focus. If there were errors, the developer must correct them.

Adding Comments

You can add comments to your logic. Commented code appears in blue. There are three types of comments:

- **Rest-of-line**—A comment of this type begins with double-backslash (\\) and includes any text that follows in the line. This is generally useful to comment out full lines of unnecessary code. You can comment out code with this type of comment using the Comment option from the popup menu.
- **In-line**—A comment can be enclosed within quotation marks. Logic can appear after the comment, thus in this sense the comment is in-line.
- **Parser**—When logic refers to objects that no longer exist, RapidPLUS automatically comments out the entire line and adds explanatory remarks enclosed by curly brackets near the name of the missing object. You can use this type of comments the same way you do with in-line comments, but it is not recommended, for the sake of code clarity.

Logic Palette

The Logic Palette aids in the process of quickly appending logic to the Logic Editor. Figure A-4 shows the Logic Palette in Objects by Type view.

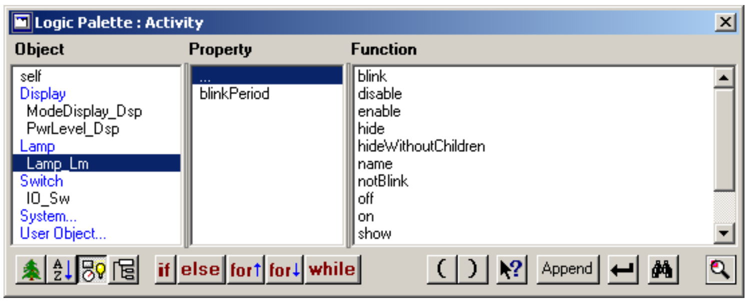


Figure A-4: The Logic Palette

The Objects by Type view, shown in Figure A-4, lists the objects available in the application according to their category. The categories are listed in blue while the objects appear indented under each category. This is usually the most convenient way to look at the available objects. Other views include Objects Tree view, Objects by Name view, and Mode Tree view. The Mode Tree view lists the available modes and not the objects.

Using the Logic Palette

You append logic from the Logic Palette to the Logic Editor by selecting the object or mode of concern, selecting one of its properties, and then one of that property's functions or events. If you wish only to append an object's name, simply double click it

Press a letter key in order to jump to the first function that begins with that letter. Press the key repeatedly in order to cycle through all the functions that begin with that letter. This is common behavior to all lists in RapidPLUS.

The Logic Palette also includes special buttons to append flow-control statements, such as " if" and "else" blocks and loops such as "for" and "while". Other than these, three logic operator buttons are also available when editing conditions: "and", "or" and "not".

Operator Precedence

Two more buttons are available in the Logic Palette for left and right brackets. These are used to set precedence and solve syntax issues.

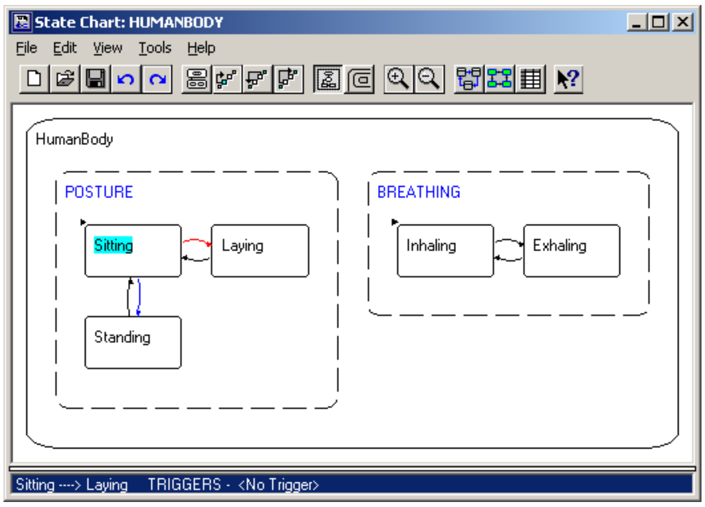
RapidPLUS evaluates arithmetic operations from left to right and not by the operator's arithmetic precedence. Therefore in RapidPLUS syntax, the value of 2+3*4 is 20 and not 14 as you might expect. To get the expected result, you should use brackets: 2+(3*4).

Inspecting Objects

At the bottom-right corner of the Logic Palette is a button named “Examine Object Contents, F6”. This button opens the Inspect tool. During runtime you can use the Inspect tool to see the values of the properties of different objects in your simulation. You can open the Inspect tool by either clicking this button, or as its name suggests, by pressing the F6 key.

State Chart

The State Chart is a tool that shows you the different modes of the system in a topographic fashion. Figure A-5 shows the State Chart in Fit view.



Sitting ---> Laying TRIGGERS - <No Trigger>

Figure A-5: The State Chart in Fit view

There are two possible views to use with the State Chart:

- **Fit**—The graph is scaled to fit the window. This view works best for daily use.
- **Normal**—The graph may spread outside the boundaries of the window. This is the best view for printing the graph on large sheets with a plotter.

In the State Chart, exclusive modes are drawn with solid edges and their name in black, while concurrent modes are drawn with dotted edges and their name in blue. The selected mode’s name is highlighted in cyan. Transitions going out of the selected mode appear in blue. The selected transition appears in red and its details are shown at the bottom of the window.

You can select the number of levels displayed in the chart. For applications with complex mode trees that have several generations, a low value gives a clear perspective on the relations between high-level behaviors of the system, while a high value lets you see the relations at the concrete behavior level. To change this value, select Options form the Tools menu. The Chart Options dialog box opens. Once the dialog box is open, set the “No. of Levels Shown” value.

In the Chart Options dialog box you can also select Number Transitions. This will number the transitions in the chart for easy reference.

Prototyper

The Prototyper is the tool in which you verify your RapidPLUS simulation. Figure A-6 shows the Prototyper running a simulation of a CD player.

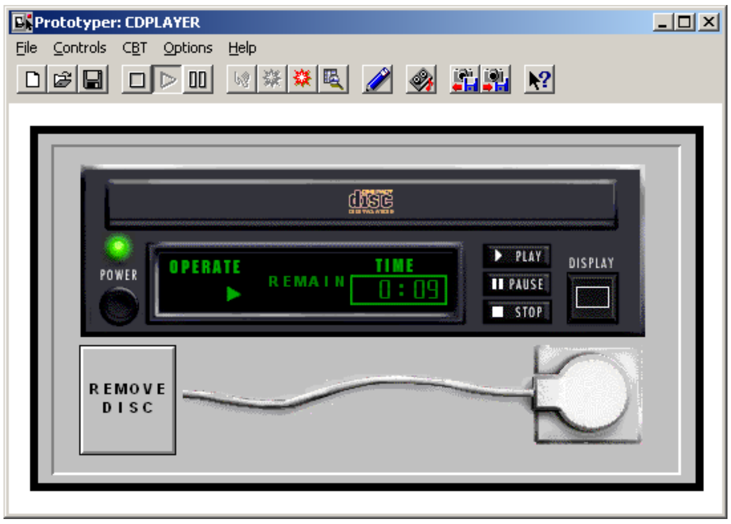


Figure A-6: The Prototyper running a simulation

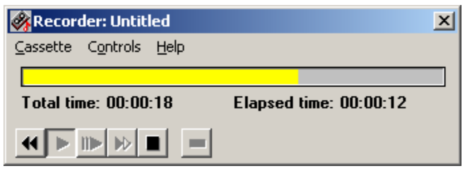
While the Prototyper is running a simulation[LS3], you can perform first level debugging by looking at the Mode Tree and noticing the active modes. This can be done only when tracing is on. To enable tracing, select Trace from the Options menu of the Prototyper. The active modes in the application will be highlighted in light gray. If your simulation doesn't operate as expected, looking at the active modes can tell you a lot about why that might be.

States

Two buttons in the Prototyper's toolbar are used for saving and loading the state of the system. The state is a runtime snapshot of the system that consists of the status of all the objects and modes in the system at a given time.
By saving the state of the system at a given point, you can initialize the system to that specific point on the next verification run. This is useful if you wish to test a specific scenario and want to save the time of bringing the system to the test point.

Recording Scenarios

Another feature of the Prototyper is the Recorder, shown in Figure A-7. The Recorder allows you to record full usage scenarios and then play them back at a later time.



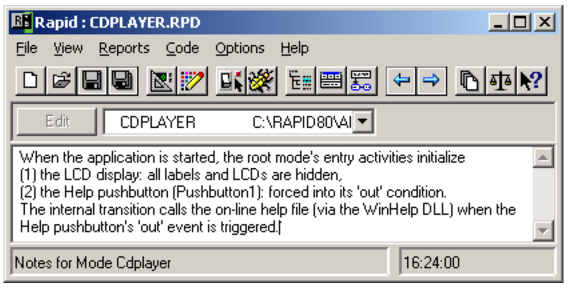
Total time: 00:00:18 Elapsed time: 00:00:12

Figure A-7: The Recorder playing back a previously recorded scenario

The recorded scenarios can be saved to an easily editable text file, where each event in the system is listed with its time stamp. The file can be edited for fine-tuning the scenario.
The recorded scenarios can be used to test the simulation's response from different initial states.

Adding Notes

You can add notes to any object and mode in your application. The notes can help clarify the purpose of the objects or modes, and to summarize in human language what an object is responsible for and what a mode represents.
To add notes to an object or a mode, simply select the relevant object or mode, and type in the note in the Notes area at the bottom of the Application Manager. Figure A-8 shows a note for the root mode of a CD player.



When the application is started, the root mode's entry activities initialize
(1) the LCD display: all labels and LCDs are hidden,
(2) the Help pushbutton (Pushbutton1): forced into its 'out' condition.
The internal transition calls the on-line help file (via the WinHelp DLL) when the Help pushbutton's 'out' event is triggered.

Notes for Mode Cdplayer

16:24:00

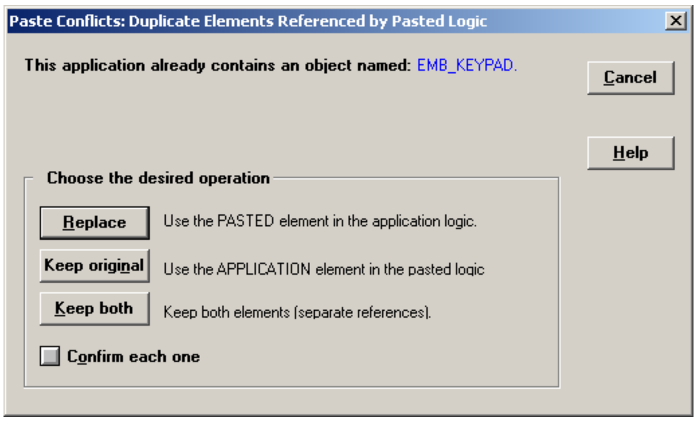
Figure A-8: The Notes area of the Application Manager

Copy & Paste

Copy and paste can be done across RapidPLUS simulations, i.e., you can copy elements from one simulation and paste them in another one. The following elements can be copied:

- **Object**—Only the object is copied.
- **Block of logic**—This can be a set of destinations, triggers, actions, or activities. As mentioned before, if a destination is copied, all the triggers for that transition and all the actions for these triggers are copied with it. If a trigger is copied then all actions for that trigger are copied with it. Al objects referenced by that logic are also copied.
- **Branch of modes**—Copying a branch of modes causes all the logic in the copied modes and all the objects referenced by that logic to be copied as well.

When pasting copied elements into a different simulation, conflicts with existing elements may occur. In this case a dialog will appear asking you what to do, as shown in Figure A-9.



Paste Conflicts: Duplicate Elements Referenced by Pasted Logic

This application already contains an object named: EMB_KEYPAD.

Choose the desired operation

Replace	Use the PASTED element in the application logic.
Keep original	Use the APPLICATION element in the pasted logic
Keep both	Keep both elements (separate references).

Figure A-9: Conflicts may occur when pasting between applications

As you can see from Figure A-9, you have the option of replacing the present element with the pasted one, keeping the original and discarding the pasted element, or keep both elements. If you choose to keep both, the pasted element's name will be changed.

Appendix B:

Answers to Course Questions

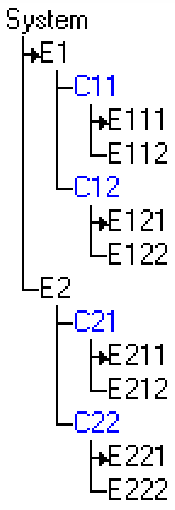
- Day 1
- Day 2

Day 1

Answer 1-1:
There are several acceptable answers here. One of them is: ***<u>Idle</u>*** and ***Menu***.

Answer 3-1:
The correct answer is:

Legal	Illegal	Transition
☑	☐	E1⇨E2
☐	☑	C22⇨C21
☐	☑	E111⇨E121
☑	☐	C22⇨E222
☑	☐	E221⇨E111
☑	☐	E121⇨System



Answer 3-2:
The correct answers are listed:

- **Event1 ! Event2**

  2. When either event takes place.

- **Event & Condition1 or Condition2**

  1. When the event is generated and either condition is True.

- **Event1 or Event2 & Condition**

  3. Never, illegal trigger.

Answer 3-3:
The minimal number of transitions required is 3.

Answer 3-4:
The answer to this question is solution dependent. The solution with the minimal number of transitions uses three event-only triggers.

Answer 4-1:
The property used was *contents*.

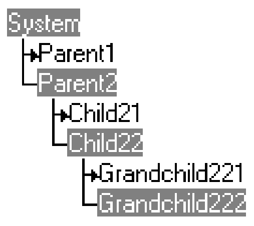
Answer 4-2:
Following are the answers to the three questions presented:

- When entering ***Operate*** mode, RapidPLUS executes the mode's entry activity, which in this case turns the LED on.
- The LED can either blink or stay on only if the television is ***On***. This mode is a child of the ***Plugged*** mode and when we exit the ***Plugged*** mode, all its active child modes are exited also. ***On*** mode has an exit activity that is executed when the mode deactivates, which turns the LED off.
- We can either put the *lamp off* activity as an ***On*** mode exit activity or as an exit activity of both ***Standby*** and ***Operate***. Both modes need to exhibit this activity upon deactivation. Since both modes are the only child modes of mode ***On***, we can save redundant code by putting the activity in the parent mode ***On***.

Answer 5-1:
The answer to this depends on the implementation. In most cases, at this stage the answer would be from left to right, since history transitions were not learnt yet.

Answer 6-1:
The Answer is:

- Default: Parent2 and Child21
- History: Parent2, Child22 and Grandchild221
- Deep-history: Parent2, Child22 and Grandchild222



Answers to the review questions:

1. The state machine may ignore the default mode when the type of transition is either history or deep history, or when a junction transition is implemented with condition-only transitions. In these cases the child that is activated is not necessarily the default child under the parent.
2. Yes, by exiting its parent.
3. Yes, if that mode is the default under the parent, and the transition that activated the parent is a default transition.
4. Graphic objects that are usually used only for improving the appearance of the simulation. These include lines, circles, etc.
5. An event is a momentary notification of a change in an object's status while a condition is an evaluation of the object's current state. Events are likened to interrupts and conditions to polling.

6. A system exhibits different behaviors in each of its modes. The behaviors it exhibits when entering a mode are that mode's entry activities. Those represented while the mode is active are mode activities. And the ones exhibited when exiting the mode are exit activities.

Day 2

Answer 8-1:

It is clear in this exercise that we can use a general use timer, since each mode needs only one timer, and every mode needs a different amount of time counted.

Answer 10-1:

The concurrency is between two subsystems of the television: its display and audio subsystems. Only when the television is operating do these two subsystems present independent behaviors, hence the concurrency should be under the ***Operate*** mode.

Answers to the review questions:

1. Dedicated timers are timers that serve a specific purpose, used when a specific amount of time needs to be counted in several different situations. General use timers are used when different lengths of time need to be counted one at a time.
2. When several transitions are made into a mode, but the behavior exhibited by the system upon entering that mode is dependent on the originating mode.
3. When we want the same behavior to be exhibited when exiting a mode, regardless of the target mode.
4. When the system exhibits a specific data-dependent behavior (e.g., changing the station on a radio) within a mode, but only in response to a trigger (e.g., a radio button being pushed in). The alternative is to have a different mode for each possible data (e.g., each station) that will exhibit the desired change of data.
5. Entry activities of the mode are executed first. Then, while in the mode, its mode activities are executed, with its internal actions. The exit activities are executed next, when exiting the mode. After they are all done, the transition actions are executed before entering the target mode.

1. [LS1]It looks very odd having Chapters 3, 5, 6 here. It looks like something was skipped… I suggest removing this additional information for Chapter 3.
2. [LS2]It is very unclear what's getting stitched to which. Is the emb. eng. interface just getting stitched to the RTOS, then the application API is stitched to API calls for the embedded hardware? Or is the embedded engine interface stitched to both the RTOS and the generated interface, and "the appropriate API calls for the embedded hardware" is just tacked on for more information?
3. Try breaking it down into separate sentences.
4. [LS3]Why "a simulation" above, and "an application" here?