Max External Tutorial

Version 2.1 (January, 1998) by Ichiro Fujinaga

This document is a tutorial for writing external objects for Max 3.5. It assumes that the reader is familiar with the Max environment and the C Programming Language. This document is intended to expand upon the material presented by David Zicarelli in his *Writing External Objects for Max* (1996) and is based on a tutorial started by Dale Stamman while at McGill University. It is strongly recommended that the reader study both documents before attempting to create an external Max object. Several examples are provided to demonstrate this process. Max externals (external objects) can be created using Think C, Symantec C++, and CodeWarrier.

This version (2.0) describes the development of Max externals (PowerPC only) using CodeWarior on PowerPC. If you are using Think C or Symantec C++ compilers or on 68k machines please refer to the version 1 of this document.

Developing Max External Object with CodeWarrior

This tutorial will explain how to create PowerPC native Max externals using MetroWerks Codewarrior (Pro 2) Refer also to Zicareli (1996, 12–8). A very simple external object called **bang** will be created. Refer to Figure 1. for the source code of bang.c. The explanation of how **bang** works and writing Max external objects is provided later. First, some preparations are in order.

Creating a PPC Max External Object (shared library) with CodeWarrior Pro 2

1. Make sure both Max 3.5.x with Software Develpers Kit and CodeWarrior are properly installed.
2. Launch CodeWarrior IDE 2.1.
3. Select New Project... from the File menu.
4. In the dialog box (Select project stationary), use the MacOS:C_C++:MacOS Toolbox:MacOS Toolbox PPC Standard Console:Std C Console PPC. Name the new project, e.g., bang.µ (option-M). A Project window named bang.µ should open.
5. Remove the ANSI Libraries folder in the project window by clicking on the name then select Remove Selected Items in the Project menu.
6. Remove the Sources folder in the project window by clicking on the name then select Remove Selected Items in the Project menu.
7. Select New from the File menu. Enter the C source code into this window or copy a source file (bang.c) into the folder then drag-and-drop the file into the Project window.
8. Select Add Files... from the Project menu to add MaxLib, which can be found in Max::Software Development Kit::Max #includes, to the project. (Close the Access Path message box.) If you are writing MSP externals, you will also need to add SoundLib and Max Audio Library.

9. Select PPC Std C Console Settings... from the Edit menu. Select PPC Target from the Target Settings Panels. Change the Project Type from Application to Shared Library, Change the File Name to name of the object, e.g., bang, Creator to max2, and File Type to ????.
10. Select PPC Linker from the Target Settings Panels. Uncheck Generate SYM File. Type main in Main: under EntryPoints.
11. Select PPC PEF from the Target Settings Panels. Check Expand Uninitialized Data. Close the PPC Debug MacOS Toolbox Settings window and save it.
12. To compile the code, select Make from the Project menu.
13. Run Max on a PPC Mac. Create a new patcher and create a new box. Type the object name into the box and external object will be created. The location of the object should be specified in the File Preferences... in the Options menu of Max.

[see also Zicarelli (1996, 12–4)]

```
// bang.c --    A very simple Max external object.
//              Outputs a bang when a bang is received.
//              97/03/08 IF
//              98/01/13 IF CodeWarrior/PPC only version

#include "ext.h"         // Required for all Max external objects

void *this_class;        // Required. Global pointing to this class

typedef struct bang      // Data structure for this object
{
   Object b_ob;          // Must always be the first field; used by Max
   void *b_out;          // Pointer to outlet. need one for each outlet
} Bang;

// Prototypes for methods: need a method for each incoming message
void *bang_new(void);          // object creation method
void bang_bang(Bang *bang);    // method for bang message

void main(void)
{
   // set up our class: create a class definition
   setup(&this_class, (method) bang_new, 0L, (short)sizeof(Bang), 0L, 0);

   addbang((method) bang_bang); // bind method "bang_bang" to the "bang" message
}

void *bang_new(void)
{
   Bang *bang;

   // create the new instance and return a pointer to it
   bang = (Bang *)newobject(this_class);

   bang->b_out = bangout(bang);    // create a bang outlet

   return(bang);                   // must return a pointer to the new instance
}

void bang_bang(Bang *bang)
{
   outlet_bang(bang->b_out);  // simply bang!
}
```

Figure 1. Source code for bang.c

Writing Max External Objects

To create an external Max object, you write a code resource (68k) or a shared library (PPC). When you type the name of your object into an empty box in a Max patcher window, its code resource file is opened and its contents loaded into memory. The object is then created and able to receive messages from the Max environment. How your object will respond to the various messages is determined by the code you have written.

Your code for an external Max object will consist of a main function and functions (methods) that respond to specific Max messages sent to your object by the Max environment.

The sturcture of a minimal external object can be divided into four sections:

- intialization\
- main()
- definition of the method to create a new object
- definition of methods that bind to other messages

The intializations consists of the necessary #include files, object structure definition, global variable declarations, and function prototypes. The main function, which is called only once when the user types the name of your object into a box in a Max patcher window for the first time, will define your objects class via `setup()` function and binds methods that will be used for incoming messges. The only requisite method for any class definition is the method that creates new objects. Within this method, memory for the new object is allocated and inlets and outlets are defined. Finally, methods that respond to other messages and other functions are defined. An explantion of each of these four sections are given below using a very simple object called **bang,** which simply outputs a bang upon a bang input. (See Figure 1 for the complete source code.)

The **bang** object: Initialization

The following lines are required for all objects:

```
#include "ext.h"        // Required for all Max external objects
void *this_class;       // Required. Global pointing to this class
```

The next step is to define a data structure for the **bang** Max object. This structure *must* start with a field called an Object. The Object contains references to the **bang** object's class definition as well as some other information. It is used by Max to communicate with the **bang** object. The following is the data structure for the **bang** object:

```
typedef struct bang     // Data structure for this object
{
    Object b_ob;        // Must always be the first field; used by Max
    void *b_out;        // Pointer to an outlet
} Bang;
```

It is a Max convention to start the names of each field in the data structure with a lower case letter followed by an underscore (e.g. b_out).

After the object's data structure has been declared, the class methods that will respond to Max messages need to be declared. Your object will do its work by responding to messages from the Max environment. Objects commonly receive integer and float messages in their inlets. Your object's methods will process these numbers in some way and then send out messages using the object's outlets.

Your code must include methods (functions) that can respond to each message your Max object will receive. The **bang** object will receive a "new" message when someone types its name into a box in a Max patcher window. Therefore it is necessary to provide a method that will handle this message and create a new instance of the **bang** object. The **bang** object is also expected to sent out a "bang" message on the outlet, upon a receipt of a "bang" in the left inlet. Methods will have to be written to handle this message. The declaration (prototypr) of these methods is shown below.

```
// Prototypes for methods: need a method for each incoming message
void *bang_new(void);       // object creation method
void bang_bang(Bang *d);    // method for bang message
```

The **bang** object: main()

When your object is created by Max for the first time, Max will load your code resource into memory and create the first instance of your class. At this time, Max will call your code resource's main function once and only once. The main function specifies how your object should be initialized. The main function needs to do the following:

1. Set up your class: allocate memory for the object and specify methods for the creation of instances of your object.
2. Define messages that the object can respond to and bind each message to a method.

Here is the `main()` function of the **bang** object:

```
void main(void)    // main receives a copy of the Max function macros table
{

     // set up our class: create a class definition
     setup((&this_class, (method) bang_new, 0L, (short)sizeof(Bang), 0L, 0);

     addbang((method) bang_bang); // bind method "bang_bang" to the "bang" message
}
```

The setup function creates a definition of the **bang** object class, which will be used by the `bang_new` method to create new instances of the **bang** object. In the above call to the setup function for the **bang** object, `this_class` is the global variable declared at the beginning of the code. The second argument, `bang_new,` is a pointer to the instance creation method `bang_new.` This is the method that will be called when the object receives a "new" message from the Max environment. Since the **bang** object does not require any special memory cleanup when it is removed from the Max environment, 0L is used in place of a pointer to a `bang_free` method. The memory occupied by the **bang** object and all of its inlets and outlets will be removed automatically by Max.

The next argument to setup allocates memory for the class. In this example, `sizeof(Bang)` is used to determine the number of bytes of memory needed. Since we are not creating a user interface object, the next argument to menufun will be 0L. The final 0 indicates that there is no argument to this object.

As mentioned above, the code must provide a method for each message you want to respond to. In the main function, each method should respond to the message with the functions: `addint, addinx, addbang, addmess,` or `addft.` Since the **bang** object only responds to the "bang" message, only one method, `bang_bang,` is needed. In order to bind the bang_bang method, which will output a "bang", to a "bang" input message, we use the routine `addbang(bang_bang).`

The **bang** object: The object creation function

When a user creates a new instance of your object by typing the name bang into a box in a Max patcher window, opening a file with your object already in it, or by cutting and pasting your object, your object will receive a “new” message. This is a request to your creation method to create an object that is an instance of your class. The creation function then handles any arguments that were typed in the box in the Max patcher window, initializes data fields, and creates the object’s inlets and outlets. Finally, the creation function returns a pointer to the new instance of the object. These actions are shown in the method `bang_new` listed below.

```
void *bang_new(void)
{
     Bang *bang;

     // create the new instance and return a pointer to it
     bang = (Bang *)newobject(this_class);

     bang->b_out = bangout(bang);     // create a bang outlet

     return(bang);          // must return a pointer to the new instance
}
```

The function, `newobject,` is used to create a new instance of the class **bang.** The argument, `this_class,` is the global variable that points to this class. This pointer was set by the setup function in the main function.

When your object is created, Max automatically creates one inlet, but other inlets and outlets must be explicitly defined. Using the `bangout` function, an outlet (that only outputs “bang” messages) will be created and returns a pointer, which will be stored in the object’s data field `b_out.`

Finally, `bang,` the pointer to the new instance of our object that was returned by the call to `newobject,` must be returned from the function `bang_new.`

Now we have a new instance of our object represented as a “bang” box in a Max patcher window. It is now waiting to receive “bang” messages that will cause its method to do the specified operation, namely, ouput a “bang”. We will now examine how this is done.

The **bang** object: Handling the “bang” message

```
void bang_bang(Bang *bang)
{
     outlet_bang(bang->b_out);   // simply bang!
}
```

When a “bang” message arrives at the object’s left inlet, the `bang_bang` function (method) is called. This happens, because in the `main()` the “bang” messge, was bound to this function `bang_bang()` by the function:

```
addbang(METHOD bang_bang);
```

The `bang_bang` method simply sends a “bang” messages via the outlet. The method calls the Max function `outlet_bang` to cause the “bang” to be output. In the object creation function, `bang_new` (see above), an outlet was created for this object with the statement:

```
bang->b_out = bangout(bang).
```

This function returned a pointer to the object’s outlet which we stored in the struct field `bang->b_out.`

The **add** object: Inlets and arguments

A simple object **add** will be used to introduce how to add inlets and arguments to your object. This object basically functions as the Max built-in "+" object. It ouputs the sum of two integers: the number coming in on the left inlet plus the number stored in the object which can be either specified via the right inlet or in the argument inside the object's box. The source code is shown in Figure 2.

```
/*   add.c -- 97/03/24 IF (based on Dale Stammen's diff)
**            98/01/14 for PowerPC only
**   This code resource defines an object similar to the standard "+" max object.
**   The add object has 2 inlets and 1 outlet.  Left inlet accepts bang and integers,
**   right inlet accepts integers, and outlet outputs the adderence of the 2 inputs.
*/

#include "ext.h"       // Required for all Max external objects

typedef struct add     // Data structure for this object
{
     Object a_ob;       // Must always be the first field; used by Max
     long a_valleft;    // Last value from left outlet
     long a_valright;   // Last value from right outlet
     long a_valtotal;   // Value to be sent to outlet
     void *a_out;       // Pointer to outlet, need one for each outlet
} Add;

// Prototypes for methods: you need a method for each message you want to respond to
void *add_new(long value);           // Object creation method
void *add_int(Add *add, long value); // Method for message "int" in left inlet
void *add_in1(Add *add, long value); // Method for message "int" in right inlet
void *add_bang(Add *add);            // Method for bang message
void *add_assist(Add *add, Object *b, long msg, long arg, char *s); // Assistance method


void main(void)             // main receives a copy of the Max function macros table
{
     // set up our class: create a class definition
     setup(&this_class, (method)add_new, 0L, (short) sizeof(Add), 0L, A_DEFLONG, 0);

     addbang((method)add_bang);  // bind method "add_bang" to the "bang" message

     addint((method)add_int);    // bind method "add_int" to int's received in the left
inlet

     addinx((method)add_in1,1);  // bind method "add_in1" to int's received in the right
inlet
}


/*************************************************************************************
add_new(long value)

inputs:       value -- the integer from the typed argument in the object box
description:  creates a new instance of our class add.  Called once when the code
              resource is loaded.
returns:      pointer to new instance
*************************************************************************************/

void *add_new(long value)
{
     Add *add;

     add = (Add *)newobject(this_class);   // Create new instance and return a pointer to
it

     add->a_valright = value;    // Initialize the addition value
     add->a_valleft = 0;
     add->a_valtotal = value;

     add->a_out = intout(add);   // Create our outlet
```

```
    intin(add,1);               // Create the right inlet

    return(add);                // Must return a pointer to the new instance
}

/*********************************************************************************
add_int(Add *a, long value)

inputs:       add      - pointer to Add object
              value    - value received in the inlet
description:  adds the right value with the incoming value. Stores the new left inlet
              value as well as the total and outputs the total.
returns:      nothing
**********************************************************************************/

void *add_int(Add *add, long value)
{
    add->a_valleft = value;     // Store the value received in the left inlet

    add->a_valtotal = add->a_valleft + add->a_valright; // Add the right inlet value with
the left

    add_bang(add);              // Call bang method right away since it's the left inlet
}

/**********************************************************************************
add_in1(Add *add, long value)

inputs:       add      - pointer to our object
              value    - value received in the inlet
description:  stores the new right value, calculates and stores the new adderence between
              the left and right value
returns:      nothing
***********************************************************************************/

void *add_in1(Add *add,long value)

{
    add->a_valright = value;                // Store the value

    add->a_valtotal = add->a_valleft + value; // Update new total
}

/**********************************************************************************
add_bang(Add *a)

inputs:       add      - pointer to our object
description:  method called when bang is received: it outputs the current sum of the left
              and right values
returns:      nothing
***********************************************************************************/

void *add_bang(Add *add)

{
    outlet_int(add->a_out, add->a_valtotal);  // simply put out the current total
}
```

Figure 2. Source code for the add object

The **add** object: Initialization

The data structure for the add object is shown below. Note that three values are stored within the object.

```
typedef struct add      // Data structure for this object
{
    Object a_ob;        // Must always be the first field; used by Max
    long a_valleft;     // Last value sent to left outlet
    long a_valright;    // Last value sent to right outlet
    long a_valtotal;    // Value to be sent to outlet
    void *a_out;        // Pointer to outlet, need one for each outlet
} Add;
```

In the `setup` function in `main()` now has A_DEFLONG argument indicating that the object accept one integer argument in the object box.

```
setup(&this_class, add_new, 0L, (short)sizeof(Add), 0L, A_DEFLONG, 0);
```

Three methods are bound with the three typs of messages: “bang” in the left inlet, interger entered in the left inlet, and integer entered in the right inlet.

```
addbang((method)add_bang);      // bind "add_bang" to the "bang" message
addint((method)add_int);        // bind "add_int" to int received in the left inlet
addinx((method)add_in1,1);      // bind "add_in1" to int received in the right inlet
```

The **add** object: The object creation function

Unlike the **bang** object above, the `add_new` function is passed an integer argument from the object box that the user may type. The object’s variables are initialized, an outlet that output intger is created and the right inlet, which accepts integer is also created:

```
void *add_new(long value)
{
    Add *add;

    add = (Add *)newobject(this_class); // Create new instance and return a pointer to it

    add->a_valright = value;    // Initialize the add values
    add->a_valleft = 0;
    add->a_valtotal = value;

    add->a_out = intout(add);   // Create our outlet

    intin(add,1);               // Create the right inlet

    return(add);                // Must return a pointer to the new instance
}
```

The **add** object: Methods

The `add_int` method is called when an integer comes in on the left inlet. It stores the value in `a_valleft`, adds that value with `a_valright`, storing the result in `a_valtotal`, then calls the `add_bang` method to ouput the result.

```
void *add_int(Add *add, long value)
{
    add->a_valleft = value;          // Store the value received in the left inlet

    add->a_valtotal = add->a_valleft + add->a_valright; // Add the right inlet value with
the left
    add_bang(add);                   // Call bang method right away since it's the left
inlet
}
```

The add_in1 method is called when an integer comes in on the right inlet. It stores the new value in a_valright then updates the val_total.

```
void *add_in1(Add *add,long value)
{
    add->a_valright = value;                    // Store the value
    add->a_valtotal = add->a_valleft + value;   // Update new total
}
```

The add_bang method is called when a “bang” comes in the left inlet or, indirectly via add_int method, when an integer comes in the left inlet.

```
void *add_bang(Add *add)
{
    outlet_int(add->a_out, add->a_valtotal);  // simply put out the current total
}
```

The **add_assist** object: Adding to the Max’s New Object list and assistance messages

Two enhancements will be added to the **add** object: the object (**add_assist**) will be included in the Patcher’s New Object list and the assistance messages, which appears when the mouse is pointed at object’s inlets and outlets. The complete listing of **add_assist** object is in Figure 3.

To make an entry in the New Object list is very simple. All you need to do is to include the following function in your main():

```
finder_addclass("All Objects", "add_assist");  // add class to the New object list
```

If you want to add the object to the "Arithmetic/ Logic" list, you could add the following:

```
finder_addclass("Arithmetic/Logic", "add_assist");
```

In order to add the assistance messages: a method must be defined, which must be bound to the Max message “assist”, and since we will be using a resource for the string for the assistance messages, we need to copy the string from the resource. The binding and the copying is done in the main() as follows:

```
addmess((method)add_assist, "assist", A_CANT, 0);   // bind method add_assist to the
                                                    // assistance message

rescopy('STR#', ResourceID); // copy the assistance messages resource into Max’s temp file
```

ResourceID is a number that you define when creating the string resource. The rescopy function copies the string to Max’s temporary file (Max Temp 1 in the Temporary Items folder). How to create this resource is explained next. The explanation of the add_assist method will follow.

Creating a String Resource in ResEdit 2.1 for a Max External Object

1. Launch ResEdit.
2. Click on the clown to get rid of it.
3. Select New... from the File menu; move to your project folder.
4. Name your resource file with EXACTLY the same name as your project and append the name with .rsrc. For example, if your project is called projectname.µ, name your resource projectname.µ.rsrc.
5. Click the New button
6. Select Create New Resource from the Resource menu.
7. Scroll down to the resource type STR# in the Select New Type window. Make sure you select STR# and not STR. Click on OK.
8. ResEdit will now create a window called STR# ID = 128. Click on the field 1) *****. Select Insert New Field(s) from the Resource menu. In the box after The string, type in your external Max object's assistance string for the first inlet. You may use a maximum of 60 characters. Repeat step 8 for as many inlets and outlets as your Max object will need. Create them in order, with the first string being the message for inlet 1, the second for inlet 2.
9. Select Get Resource Info from the Resource menu. Enter your resource ID number in the field ID:. This number MUST match the resource ID number you define in your Max object. If you wish, you may type in the name of your resource in the field Name. This will help you remember what the resource is used for in the “resource picker window”.
10. Save your resource. Make sure it is saved to your project folder and that it has the same name as your project file with .rsrc added to the end of the name.

The **add_assist** object: `add_assist` method

```
void *add_assist(Add *add, Object *b, long msg, long arg, char *s)
{
     EnterCallback();

     // copy the appropriate message to the destination string
     assist_string(ResourceID, msg, arg, 1, 3, s);
     ExitCallback();
}
```

In the argument list for **add_assist,** d is a pointer to our object, b is a pointer to the object’s box in the Max patcher window. msg will be one of two values: 1 if the cursor is over an inlet or 2 if it is over an outlet. arg is the inlet or outlet number starting at 0 for the left inlet. s is where you will copy a C string containing your assistance information.

The function assist_string handles the posting of the assistance string in the assistance area of the Max patcher window. It will copy the correct string from the resource in the memory specified by ResourceID. (ResourceID was defined at the beginning of the code.) This resource was copied into the Max’s temp file by rescopy`()` in the `main` function. `msg` specifies if either an inlet or outlet was selected and arg is the inlet or outlets number. The argument 1 specifies that the first string in the resource corresponds to the first inlet. Likewise, the argument 3 specifies that the third string in the resource goes with the first outlet. The function assist_string will copy the selected resource string into s, which will then be displayed in the assistance area of the patcher window.

```
/*   add_assist.c -- 97/03/24 IF (based on Dale Stammen's diff)
**                  98/01/14 for PowerPC only IF
**   This code resource defines an object similar to the standard "+" max object.
**   The add object has 2 inlets and 1 outlet.  Left inlet accepts bang and integers,
**   right inlet accepts integers, and outlet outputs the adderence of the 2 inputs.
*/

#include "ext.h"        // Required for all Max external objects

void *this_class;       // Required. Global pointing to this class

#define  ResourceID 3999 // resource ID# for assistance strings created in ResEdit

typedef struct add      // Data structure for this object
{
     Object a_ob;       // Must always be the first field; used by Max
     long a_valleft;    // Last value sent to left outlet
     long a_valright;   // Last value sent to right outlet
     long a_valtotal;   // Value to be sent to outlet
     void *a_out;       // Pointer to outlet, need one for each outlet
} Add;

// Prototypes for methods: you need a method for each message you want to respond to
void *add_new(long value);       // Object creation method
void *add_int(Add *add, long value); // Method for message "int" in left inlet
void *add_in1(Add *add, long value); // Method for message "int" in right inlet
void *add_bang(Add *add);            // Method for bang message
void *add_assist(Add *add, Object *b, long msg, long arg, char *s); // Assistance method

void main(void)         // main receives a copy of the Max function macros table
{
     // set up our class: create a class definition
     setup(&this_class, (method)add_new, 0L, (short) sizeof(Add), 0L, A_DEFLONG, 0);

     addbang((method)add_bang);       // bind method "add_bang" to the "bang" message
     addint((method)add_int);         // bind method "add_int" to int's received in the
                                      // left inlet
     addinx((method)add_in1,1);       // bind method "add_in1" to int's received in the
                                      // right inlet
     addmess((method)add_assist, "assist",A_CANT,0);     // bind method "add_assist" to
                                                         // the assistance message
     rescopy('STR#', ResourceID);     // copy the assistance messages resource into Max’s
                                      // temp file
     finder_addclass("All Objects", "add_assist");  // add class to the New object list
}


/**********************************************************************************
add_new(long value)

inputs:       value -- the integer from the typed argument in the object box
description:  creates a new instance of our class add.
              Called once when the code resource is loaded.
returns:      pointer to new instance
*************************************************************************************/

void *add_new(long value)
{
     Add *add;

     add = (Add *)newobject(this_class);   // Create the new instance
     add->a_valright = value;    // Initialize the addition value
     add->a_valleft = 0;
     add->a_valtotal = value;
     add->a_out = intout(add);   // Create our outlet
     intin(add,1);               // Create the right inlet
     return(add);                // Must return a pointer to the new instance
}
```

```
/*********************************************************************************
add_int(Add *a, long value)

inputs:       add      - pointer to Add object
              value    - value received in the inlet
description:  adds the right value with the incoming value. Stores the new left inlet
              value as well as the total and outputs the total.
returns:      nothing
*********************************************************************************/

void *add_int(Add *add, long value)
{
    add->a_valleft = value;          // Store the value received in the left inlet

    add->a_valtotal = add->a_valleft + add->a_valright; // Add the right with the left
    add_bang(add);              // Call bang method right away since it's the left inlet
}

/**********************************************************************************
add_in1(Add *add, long value)

inputs:       add  -- pointer to our object
              value -- value received in the inlet
description:  stores the new right value, calculates and stores the
              new adderence between the left and right value
returns:      nothing
**********************************************************************************/

void *add_in1(Add *add,long value)
{
    add->a_valright = value;                  // Store the value
    add->a_valtotal = add->a_valleft + value; // Update new total
}


/**********************************************************************************
add_bang(Add *a)

inputs:       add -- pointer to our object
description:  method called when bang is received: it outputs the current
              sum of the left and right values
returns:      nothing
**********************************************************************************/

void *add_bang(Add *add)
{
    outlet_int(add->a_out, add->a_valtotal);  // simply put out the current total
}

/**********************************************************************************
void *add_assist(a, b, msg, arg, s)

inputs:       add      - pointer to Add object
              b        - pointer to the Add object's box
              msg      - specifies whether request for inlet or outlet info
              arg      - selected inlet or outlet number
              s        - destination for assistance string
description:  method called when assist message is received: it outputs the correct
              assistance message string to the patcher window
returns:      nothing
**********************************************************************************/

void *add_assist(Add *add, Object *b, long msg, long arg, char *s)
{
    // copy the appropriate message to the destination string
    assist_string(ResourceID, msg, arg, 1, 3, s);
}
```

Figure 3 Source code for add_assist **object**

The **minimum** object: Float, Atom, and list

Thus far, the only data type we have been using is an integer type, namely long. In this section, we'll introduce the float data type, the Atom data type, and the list, which is an array of Atoms.

The float data type is similar to long except that it involves floating-point numbers. Max provides macros and functions to handle floats very similar to longs, e.g., to add left inlets you would use:

```
addint(long_method);
```

for inlet that accepts long and use:

```
addfloat(float_method);
```

for inlet that accepts float.

An Atom is a special data type (a structure) that allows any of the four data types (long, float, Symbol, Object) used in Max to be stored. Here is how it is defined:

```
union word          /* union for packing any data type */
{
     long      w_long;
     float     w_float;
     Symbol    *w_sym;
     Object    *w_obj;
};

typedef struct atom     // and an atom which is a typed datum
{
     short          a_type;   // from the defs below
     union word     a_w;
} Atom;
```

The struct member a_type specifies what type of data is stored in a_w, and it could be any of the following:

```
#define A_NOTHING       0    // ends the type list
#define A_LONG          1    // Type-checked integer argument
#define A_FLOAT         2    // Type-checked float argument
#define A_SYM           3    // Type-chceked symbol argument
#define A_OBJ           4    // for argtype lists; passes the value of sym
#define A_DEFLONG       5    // long but defaults to zero
#define A_DEFFLOAT      6    // float, same default
#define A_DEFSYM        7    // symbol, defaults to ""
```

A list in Max is simple an array of Atoms. A list will be used if you declare a method to receive its arguments with A_GIMME, typically in either the setup function:

```
setup(&class, (method)minimum_new, 0L, (short)sizeof(Minimum), 0L, A_GIMME, A_NOTHING);
```

or a method that responds to the “list” message:

```
addmess((method)minimum_list, "list", A_GIMME, A_NOTHING);
```

Then your method, `minimum_list` in the example above, will be passed a list. This is done by `argc` (`short`) and `argv (Atom *)`. `argc` is the number of Atoms and `argv` points to the first Atom in the array. Here is an example:

```
void minimum_list(Minimum *x, Symbol *s, short argc, Atom *argv)
```

The Symbol *s contains the message itself (in this case, “list”). The object **minimum** illustrates use of these data types (see Figure 4).

```
/* minimum.c -- output the minimum of a group of numbers ------- */
// From the Max 3.5 distribution. Slightly modified by IF 97/04/02
// For PowerPC only 98/01/14 IF
// Topics covered: floats, Atoms, lists


#include "ext.h"

#define MAXSIZE 32
#define ResourceID 3008

typedef struct minimum
{
     struct object m_ob;
     Atom m_args[MAXSIZE];
     long m_count;
     short m_incount;
     short m_outtype;
     void *m_out;
} Minimum;


void *class;
void DoAtomMin(Atom *min, Atom *new);
void minimum_bang(Minimum *x);
void minimum_int(Minimum *x, long n);
void minimum_in1(Minimum *x, long n);
void minimum_float(Minimum *x, double f);
void minimum_ft1(Minimum *x, double f);
void minimum_list(Minimum *x, Symbol *s, short ac, Atom *av);
void minimum_assist(Minimum *x, void *b, long m, long a, char *s);
void *minimum_new(Symbol *s, short ac, Atom *av);


void main(fptr *f)
{

     setup((&class, (method)minimum_new,0L, (short)sizeof(Minimum),
               0L, A_GIMME, 0);
     addbang((method)minimum_bang);
     addint((method)minimum_int);
     addinx((method)minimum_in1, 1);
     addfloat((method)minimum_float);
     addftx((method)minimum_ft1, 1);
     addmess((method)minimum_list, "list", A_GIMME, 0);
     addmess((method)minimum_assist, "assist", A_CANT, 0);
     finder_addclass("Arith/Logic/Bitwise", "minimum");
     rescopy('STR#', ResourceID);
}


void DoAtomMin(Atom *min, Atom *new)  // check to see if new minimum,
                                      //depending on the data types
{
     if (min->a_type==A_NOTHING) // At startup set minimum
     {
          *min = *new;
          return;
     }
     if (min->a_type==A_FLOAT) // old is FLOAT
     {
          if (new->a_type==A_FLOAT) // new is FLOAT
          {
               if (new->a_w.w_float < min->a_w.w_float)
                    min->a_w.w_float = new->a_w.w_float;
          }
          else //new is LONG, old is FLOAT
          {
               if ((float)new->a_w.w_long < min->a_w.w_float)
                    min->a_w.w_float = (float)new->a_w.w_long;
          }
     }
     else // old is LONG
     {
          if (new->a_type==A_LONG) // new is LONG
          {
```

```
            if (new->a_w.w_long < min->a_w.w_long)
                min->a_w.w_long = new->a_w.w_long;
        }
        else // new is float, old is LONG
        {
            if ((long)new->a_w.w_float < min->a_w.w_long)
                min->a_w.w_long = (long)new->a_w.w_float;
        }
    }
}

void minimum_bang(Minimum *x)
{
    register short i;
    Atom themin;
    long res;
    double fres;

    themin.a_type = A_NOTHING;
    for (i=0; i < x->m_count; i++)   // check if any of the input is a new minimum
        DoAtomMin(&themin,x->m_args+i);
    if (x->m_outtype==A_LONG)
    {
        if (themin.a_type==A_LONG)
            res = themin.a_w.w_long;
        else
            res = (long)themin.a_w.w_float;
        outlet_int(x->m_out,res);
    }
    else
    {
        if (themin.a_type==A_FLOAT)
            fres = themin.a_w.w_float;
        else
            fres = (float)themin.a_w.w_long;
        outlet_float(x->m_out,fres);
    }
}

void minimum_int(Minimum *x, long n)
{
    SETLONG(x->m_args,n);
    minimum_bang(x);
}

void minimum_in1(Minimum *x, long n)
{
    SETLONG(x->m_args+1,n);
    x->m_count = 2;
}


void minimum_float(Minimum *x, double f)
{
    SETFLOAT(x->m_args,f);
    minimum_bang(x);
}

void minimum_ft1(Minimum *x, double f)
{
    SETFLOAT(x->m_args+1,f);
    x->m_count = 2;
}

void minimum_list(Minimum *x, Symbol *s, short ac, Atom *av)
{
    register short i;

    if (ac >= MAXSIZE)
        ac = MAXSIZE - 1;
    for (i=0; i < ac; i++,av++)
    {
        if (av->a_type==A_LONG)
            SETLONG(x->m_args+i,av->a_w.w_long);
        else if (av->a_type==A_FLOAT)
            SETFLOAT(x->m_args+i,av->a_w.w_float);
    }
    x->m_count = ac;
    minimum_bang(x);
```

```
}

void minimum_assist(Minimum *x, void *b, long m, long a, char *s)

{
     assist_string(ResourceID, m, a, 1, 3, s);
}

void *minimum_new(Symbol *s, short ac, Atom *av)
{
     Minimum *x;

     x = (Minimum *)newobject(class);
     x->m_count = 2;
     if (ac)
     {
          x->m_args[1] = *av;         // intialize with the first argument
          if (av->a_type==A_LONG)
          {
               x->m_args[0].a_type = x->m_outtype = A_LONG;
               x->m_out = intout(x);
               x->m_args[0].a_w.w_long = 0;
               intin(x, 1);
          }
          else if (av->a_type==A_FLOAT)
          {
               x->m_args[0].a_type = x->m_outtype = A_FLOAT;
               x->m_out = floatout(x);
               x->m_args[0].a_w.w_float = 0;
               floatin(x, 1);
          }
     }
     else // if no argument, set to a defualt
     {
          x->m_outtype = A_LONG;
          intin(x,1);
          x->m_out = intout(x);
          SETLONG(x->m_args + 1, 0L);
          SETLONG(x->m_args, 0L);
     }
     return (x);
}
```

Figure 4. Source code for the minimum object

More Atoms and list

Max uses Atoms when passing messages between objects. If your object is going to be able to send a list out of its outlet, it will have to use a list of Atoms. Likewise, if you wish to receive lists, or more than 7 typed data in arguments from your object's box in the Max patcher, you will again have to deal with Atoms. Remember, Atoms are simply a struct that have a field of type union that allows them to contain different types of data.

It is now necessary to examine the structure of a message in Max. Consider the following message box:

```
play 100 200 2.5 stop
```

This message box contains 5 items, the symbol "play", the long integers 100 and 200, the float 2.5, and finally the symbol "stop". If this message is sent to your object, your object will actually receive the message "play", followed by a list of 4 atoms containing 100, 200, 2.5 and "stop". In other words, "play" is the message and the remaining items are its arguments. One way to make your object understand this message is to use addmess`()` in its main function.

```
addmess(max_play, "play", A_LONG, A_LONG, A_FLOAT, A_SYM, 0);      // bind method max-
play to the "play" message"
```

or with optional arguments, so that if some of the arguments are not specified by the user, the object will set them to a default values:

```
addmess(max_play, "play", A_DEFLONG, A_DEFLONG, A_DEFFLOAT, A_DEFSYM, 0);
```

But this approach requires that you always have two longs, a float and a symbol in the right order. You are also limited to a total of seven arguments using this declaration method.

There is another way for your object to receive messages and their arguments. When you declare a method to receive its arguments with A_GIMME, the arguments will be passed to your object in an argc, argv list. More about this argc, argv stuff later.

In order to tell Max to give you all of the arguments in a message, you bind your method to the message in your main function with the Max function addmess. For example, to bind the method atoms_play with the above message you would write in your main function:

```
addmess(atoms_play, "play", A_GIMME, 0);  // bind method "atoms_play" to the "play"
message"
```

This call binds the method atoms_play to the message "play". Whenever the object receives the message "play", Max will call the method atoms_play and pass it the message and a list of arguments.

A_GIMME tells Max to pass the message and its arguments without typechecking them. You are now responsible for typechecking them yourself.

You now need to write a method that will be able to receive this message and its arguments. The method atoms_play would be declared as:

```
void *atoms_play(Example *a, Symbol *mess, int argc, Atom *argv)
```

In this function declaration, a is a pointer to your object, mess is pointer to the message that called this method (in this example the, “play” message). The integer argc is the number of arguments contained in the atom list and argv is a pointer to an array of atoms containing the actual arguments. Up to 65,536 arguments can be received by a method.

If your object receives the message “play 100 200 2.5 stop”, Max will call your play function. Your atoms_play function will receive a pointer to the symbol “play” in mess, the integer 4 in argc, and finally a pointer to a list of atoms containing the values 100 200 2.5 “stop”. The code in Figure 5 shows you how to typecheck and access the data in the atom list.

```
#define MAX_ARGS  20

typedef struct example          // data structure for this object
{
     Object a_ob;
     Atom  a_list[MAX_ARGS];     // array of Atoms: list
     int   a_size;               // number of Atoms in the list
} Example;

void *atoms_play(Example *a,int argc, Atom *argv)
{
     int i;

     a->a_size = argc;
     if (a->a_size > MAX_ARGS)
          a->a_size = MAX_ARGS;

     for(i = 0; i < a->a_size; i++)
          switch(argv[i].a_type)      // type check each argument
          {
               case A_LONG:
                    SETLONG(a->a_list + i, argv[i].a_w.w_long);
                    post(“argument %ld is a long: %ld”, (long) i,argv[i].a_w.w_long);
                    break;
               case A_FLOAT:
                    SETFLOAT(a->a_list + i, argv[i].a_w.w_float);
                    post(“argument %ld is a float: %f”, (long) i, argv[i].a_w.w_float);
                    break;
               case A_SYM:
                    SETSYM(a->a_list + i, argv[i].a_w.w_sym);
                    post(“argument %ld is a symbol: %s”,(long) i,
                                                             argv[i].a_w.w_sym->s_name);
                    break;
          }
}
```

Figure 5. Typechecking an argc, argv list of atoms

This example receives a list of arguments from Max whenever the object receives the “play” message. It then checks the type of each Atom in the argv list and stores it into an internal array of Atoms. Finally, it reports to the Max window the type and value of the argument.

When working an Atom, you must be able to correctly access its various fields. In Figure 5, we examine the a_type field of an Atom to determine the type of data contained in the union. As mentioned above a_type will be either A_LONG, A_FLOAT, or A_SYM. These constants are declared in the Max #include file “ext_mess.h”.

Notice that we use the struct notation argv[i].a_type to access the a_type field. It is also possible to use the pointer argv to access the field, i.e., `(argv + i)->`a_type. You may choose whatever style suits you best.

In the above example, if the Atom contains a long (i.e., a_type == A_LONG), we want to store the argument into our internal Atom list, a_list as a long. Likewise, if (a_type == A_FLOAT) we would store it as a float, and if (a_type == A_SYM) we would store the argument as a symbol. Max provides several macros for storing an item into an atom. These are:

```
SETLONG(Atom *a, long number);
SETFLOAT(Atom *a, float number);
SETSYM(Atom *a, Symbol *s);
```

Here are the cuurent macro definitions as they appear in Max #include file "ext_mess.h".

```
#define SETSYM(ap, x)       ((ap)->a_type = A_SYM, (ap)->a_w.w_sym = (x))
#define SETLONG(ap, x)      ((ap)->a_type = A_LONG, (ap)->a_w.w_long = (x))
#define SETFLOAT(ap, x)     ((ap)->a_type = A_FLOAT, (ap)->a_w.w_float = (x))
```

These macros accomplish two things. First the macro sets the a_type field of the Atom to the correct type. This means that SETLONG will set the a_type field of the Atom to A_LONG, SETFLOAT sets it to A_FLOAT, and SETSYM sets it to A_SYM. The macro then puts the long, float, or the pointer to the symbol into the union a_w. Remember that a pointer to the symbol is stored in the union, and not the actual symbol.

In the above example we used the following line of code to call SETLONG:

```
SETLONG(a->a_list + i, argv[i].a_w.w_long);
```

In this call, a is a pointer to our Object. We use it to access the array of Atoms called a_list that is in our object's data structure. Since SETLONG requires a pointer to an Atom, we must give it a pointer to the *i* th Atom in the array. When i == 0, a->a_list + i is a pointer to the first Atom in the array a_list. Likewise, if i == 5, a->a_list + i is a pointer to the 6th Atom in the array.

Notice how we access the long field of the union a_w in the argv Atom list. We write argv[i] to access the *i* th Atom in the argv list. argv[i].a_w accesses the union a_w field of the struct atom. Finally, argv[i].a_w.w_long accesses the long value stored in the union a_w. We first access the atom, then the union, and finally the data.

Another way of putting a long value into an Atom is:

```
a->a_list[i].a_type = A_LONG;
a->a_list[i].a_w.w_long = 100;
```

Using this method you are responsible for setting the a_type field yourself.

You can use SETFLOAT the same way as SETLONG. SETFLOAT will set the a_type field to A_FLOAT, and place the float value in the float field of the union a_w (i.e., a_w.w_float). To access a float field of an Atom in the argv list in the above example, we write:

```
argv[i].a_w.w_float or (argv + i)->a_w.w_float
```

Likewise, to access this value in our internal array of Atoms we write:

```
a->a_list[i].a_w.w_float or (a->a_list + i)->a_w.w_float
```

When you want to store a symbol into an Atom, or access a symbol already in an Atom, you must remember that a pointer to the symbol is stored in the Symbol field of the union a_w. The field in the union a_w is defined as Symbol *w_sym. Therefore, in order to store a symbol into an Atom you store the pointer to the symbol and not the symbol itself. Likewise, when you access a symbol, you need to access what the pointer in the Symbol field points to. In other words, to get at a symbol, there is yet another stage of indirection.

In the above example, we use SETSYM to set the pointer to the symbol contained in the argv list into our internal Atom list a_list. Therefore, SETSYM wants a pointer to the symbol as its second argument.

```
SETSYM(a->a_list + i, argv[i].a_w.w_sym);
```

Notice how we post the actual symbol to the Max window. We use the following post function:

```
post(“argument %ld is a symbol: %s”, (long) i, argv[i].a_w.w_sym->s_name);
```

Note that in order to access our actual symbol, we must access what the symbol pointer points to:

```
argv[i].a_w.w_sym->s_name
```

In the Max #include file “ext_mess.h” a symbol is defined as the following struct:

```
struct symbol
{
    char *s_name;               /* name */
    struct object *s_thing;     /* possible binding to an object */
} Symbol;
```

Therefore, in order to access a symbol in an Atom, first access the Atom, then the union a_w, then the w_sym field and finally the s_name field of the Symbol, i.e., argv[i].a_w.w_sym->s_name.

Now that you have a list of Atoms in your object you can send it to an outlet. To do this you need to create a list outlet using the Max function:

```
Outlet *listout (void *owner)
```

In our example we would create the list outlet in the object’s creation function example_new.

```
a->a_list_outlet = listout(Example *x);
```

To send the internal list a_list out this outlet, one would use the Max function:

```
void *outlet_list(Outlet *x, Symbol *msg, int argc, Atom *argv);
```

We would call this function with the following arguments:

```
outlet_list(a->a_list_outlet, “list”, a->a_size, &(a->a_list));
```

where a->a_list_outlet is a pointer to the outlet we created with listout, “list” is the message to be sent, a->a_size is the number of Atoms in the internal Atom list, and &(a->a_list) is a pointer to the first Atom in this list.

The **atoms** object:

Notice the addmess functions:

```
addmess(atoms_list,"play",A_GIMME,0);     // bind method "atoms_list" to "play" message
addmess(atoms_list,"list",A_GIMME,0);     // bind method "atoms_list" to "list" message
```

Both of these lines of code cause the function `atoms_list` to be called when the object receives either the “play” message of the “list” message. Also notice that we requested that Max send to our object the arguments of the message as a list of atoms. This was accomplished by using A_GIMME.

The `list` Method

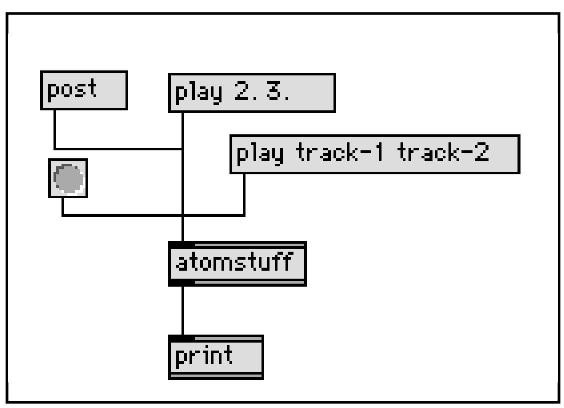
This method receives a list of atoms from Max contain the items of the list sent to your object. The number of items (or atoms) in the list is in argc. The actual atoms are stored in argv. Actually these are pointers to atoms. We then check each atom for its type before we put it in our list. The list method then sends the list of atoms out its outlet using `outlet_list`. Notice we use `&(a->a_list)` to point to our list of Atoms.

The `bang` Method

When our object receives the bang message, it simply sends the current contents of its list out its outlet using the `outlet_list` function.

The `post` Method (Zicarelli 1996, 71)

When the object receives the “bang” message, it posts the contents of its Atom list to the Max window using the function `postatom` (Zicarelli 1996, 72). Here is how to post a list of atoms:



The **mymetro** object: Clock routines

This example uses the **Clock** object (Zicarelli 1996, 60–3), which allows scheduling in Max. The routines associated wuth the **Clock** objects allows events to happen in the future. This is accomplished by assigning a functin to be executed when the clock goes off and indicate when the clock is to go off. More specifically:

1. Use `clock_new()` to create a **Clock** object and assign the function to be executed when it goes off.
2. Use `clock_set()` or `clock_delay()` to schedule the execution of the clock function at absolute time or relative time, respectively. Zicarelli recommends using `clock_delay` rather than `clock_set` (Zicarelli 1996, 61).
3. When the **Clock** is no longer needed, it should be removed with `freeobject` function.

```
/*  This code resource defines the object "mymetro" which is similar to the standard
     "metro" Max object. The metro object has 2 inlets and 2 outlets.

     "bang"    in left inlet starts metronome
     "stop"    in left inlet stops metronome
     integer   in right inlet sets tempo in ms

     left output sends bangs at each metronome interval
     right outlet outputs current time

     The object also posts messages to the Max window indicating the current state of
     mymetro.
*/

#include "ext.h"       // Required for all Max external objects

#define  ResourceID    4999     /* resource ID# for assistance strings */
#define DEFAULT_TEMPO  1000
#define MIN_TEMPO      40

typedef struct metro            /* data structure for this object */
{
     Object    m_ob;            /* must always be the first field; used by Max */
     void      *m_clock;        /* pointer to clock object */
     long      m_interval;      /* tempo in milliseconds */
     void      *m_bang_outlet;  /* pointers to bang outlet */
     void      *m_time_outlet;  /* pointers to time outlet */
} Metro;

void *metro_new(long value);
void *metro_in1(Metro *m, long value);
void *metro_bang(Metro *m);
void *metro_assist(Metro *m, Object *b, long msg, long arg, char *s);
void *metro_free(Metro *m);
void *metro_stop(Metro *m);
void *clock_function(Metro *m);

void *class;      // Required. Global pointing to this class

void main(void)
{

     /* set up our class: create a class definition */
     setup(&class, (method)metro_new, (method)metro_free, (short) sizeof(Metro), 0L,
A_DEFLONG, 0);

     /* bind method "metro_bang" to the "bang" message */
     addbang((method)metro_bang);
```

```
	/* bind method "metro_in1" to int's received in the right inlet */
	addinx((method)metro_in1,1);

	/* bind method "metro_stop" to the "stop" message" */
	addmess((method)metro_stop,"stop",0);

	/* bind method "metro_assist" to the assistance message" */
	addmess((method)metro_assist,"assist",A_CANT,0);

	/* copy the assistance messages resource into the Max temp file */
	rescopy('STR#',ResourceID);

	/* add class to the New object list */
	finder_addclass("All Objects","mymetro");
}

/**********************************************************************************
metro_new(long value)

inputs:       value - the integer from the typed in argument in the object box
description:  creates a new instance of this class metro.
returns:      pointer to new instance
*************************************************************************************/
void *metro_new(long value)
{
	Metro *m;

	m = (Metro *)newobject(class); // create the new instance and return a pointer to it

	if (value > MIN_TEMPO)           // initialize the subtraction value
	{
		m->m_interval = value;      // save tempo arguement from box
		post("mymetro tempo set to %ld", value);
	}
	else
	{
		m->m_interval = DEFAULT_TEMPO;   // set to default tempo
		post("mymetro set to default tempo of %ld ms", DEFAULT_TEMPO);
	}
	m->m_clock = clock_new(m, (method)clock_function);  // create the metronome clock

	intin(m, 1);                     // create the right inlet
	m->m_time_outlet = intout(m);    // create right outlet for time
	m->m_bang_outlet = bangout(m);   // create left outlet for ticks

	return(m);
}

/*************************************************************************************
metro_in1(Metro *m, long value)

inputs:  m      -- pointer to our object
         value -- value received in the inlet
description:       stores the new metronome tempo value
*************************************************************************************/
void *metro_in1(Metro *m, long value)
{
	m->m_interval = value;      // store the new metronome interval
	post("metronome tempo changed to %ld", value);
}

/*************************************************************************************
void *metro_bang(Metro *m)

inputs:       m -- pointer to our object
description:  method called when bang is received: it starts the metronome
*************************************************************************************/
void *metro_bang(Metro *m)

{
	long time;

	time = gettime();                // get current time
	clock_set(m->m_clock, time);     // set clock to go off now
	post("clock started at %ld", time);
}
```

```
/*************************************************************************************
void *metro_stop(Metro *m)

inputs:       m -- pointer to our object
description:  method called when myMetro receives "stop" message. Stops the metronome
*************************************************************************************/
void *metro_stop(Metro *m)

{
    long time;

    time = gettime();           // get current time
    clock_unset(m->m_clock);    // remove the clock routine from the scheduler
    outlet_int(m->m_time_outlet, time);
    post("metronome stopped at %ld", time);
}


/*************************************************************************************
void clock_function(Metro *m)

inputs:       m -- pointer to our object
description:  method called when clock goes off: it outputs a bang to be sent to the
              outlet and resets the clock  to go off after the next interval.
*************************************************************************************/
void *clock_function(Metro *m)

{
    long time;

    time = gettime();       // get current time
    clock_delay(m->m_clock, m->m_interval);   // schedule another metronome click
    outlet_bang(m->m_bang_outlet);            // send out a bang
    outlet_int(m->m_time_outlet, time);       // send current time to right outlet
    post("clock_function %ld", time);

}


/*************************************************************************************
metro_free(Metro *m)

inputs:       m -- pointer to our object
description:  method called when Metro objects is destroyed. It is used to free memory
              allocated to the clock.
*************************************************************************************/
void *metro_free(Metro *m)
{
    clock_unset(m->m_clock);    // remove the clock routine from the scheduler
    clock_free(m->m_clock);     // free the clock memory
}

void *metro_assist(Metro *m, Object *b, long msg, long arg, char *s)
{
    // copy the appropriate message to the destination string
    assist_string(ResourceID, msg, arg, 1L, 4L, s);
}
```