

Max/MSP Externals Tutorial

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This document is a tutorial for writing external objects for Max 4 + MSP 2. 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 4.0 and MSP 2.0* (2001) and *SDKreadme.txt* (2002) and is based on a tutorial started by Dale Stammen while at McGill University. Several examples are provided to demonstrate this process. Max externals (external objects) can be created using Think C, Symantec C++, and CodeWarrior.

This version (3.0) describes the development of Max/MSP externals (PowerPC only) using CodeWarrior on PowerPC running OS X. If you are using previous version of Mac OS, refer to version 2.5 of this tutorial.

Developing Max External Object with CodeWarrior

This tutorial will explain how to create PowerPC native Max externals using MetroWerks Codewarrior version 8 or later (IDE version 5.0 or later). 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.

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

1. Locate or download **sdk-beta-osx** folder.
2. Copy **c74support** folder within the **sdk-beta-osx** folder to **Metrowerks CodeWarrior 8.0/Metrowerks Codewarrior** folder.
3. Create a folder **bang** (e.g on the Desktop).
4. Copy **sdk-beta-osx/xml-project-templates/max.common.mcp.xml** to the **bang** folder and rename it **bang.xml**.
5. Launch CodeWarrior. Choose **Open** under the **File** menu and open **bang.xml**. Choose **Find and Replace...** from the **Search** menu. Enter **C74OBJECTNAME** as the find string and **bang** as the replace string. Click **Replace All**. Save and close its window.
6. Choose **Import Project...** from the **File** menu. Open **bang.xml** then save the file as **bang.mcp** in the **bang** folder. In the project window select **bang.rsrc** by clicking on it then delete it by choosing **Clear** from the **Edit** menu.
7. From **File** menu select **New Text File**. Enter the C source code into this window, then save it in the **bang** folder as **bang.c** or copy a source file (**bang.c**) into the folder.
8. To compile the code, select **Make** from the **Project** menu. If successful you should see the familiar Max external object file created in the folder **build-mac** at the same level as the **bang** folder.

9. Start Max by double-click the newly created object (or else Max will not find your object). Create a new patcher and create a new box. Type the object name (bang) into the box and the external object will be created.

```

// bang.c -- A very simple Max external object.
//           Outputs a bang when a bang is received.

#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
{
    t_object b_ob;    // Must always be the first field; used by Max
    void *b_out;      // Pointer to outlet, need one for each outlet
} t_bang;

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

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

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

void *bang_new(void)
{
    t_bang *bang;

    // create the new instance and return a pointer to it
    bang = (t_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(t_bang *bang)
{
    outlet_bang(bang->b_out);    // send a bang to the outlet bang->b_out
}

```

Figure 1. Source code for bang.c

Writing Max External Objects

To create an external Max object, you write a shared library. When you type the name of your object into an empty box in a Max patcher window, its shared library 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 structure of a minimal external object can be divided into four sections:

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

The initialization 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 object's class via `setup()` function and binds methods that will be used for incoming messages. 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 explanation of each of these four sections is 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 a `t_object`. The `t_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
{
    t_object b_ob; // Must always be the first field; used by Max
    void *b_out; // Pointer to an outlet
} t_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 send 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 (prototype) 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(t_bang *d); // method for bang message
```

The **bang** object: main()

When Max creates your object for the first time, Max will load your external object into memory and create the first instance of your class. At this time, Max will call your external’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)
{
    // set up our class: create a class definition
    setup((t_messlist **) &this_class, (method)bang_new, 0L, (short)sizeof(t_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(t_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, addft, or addftx. 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)
{
    t_bang *bang;

    // create the new instance and return a pointer to it
    bang = (t_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, output a “bang”. We will now examine how this is done.

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

```
void bang_bang(t_bang *bang)
{
    outlet_bang(bang->b_out); // send a bang to the outlet bang->b_out
}
```

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” message, 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 **diff** object: Inlets and arguments

A simple object **diff** 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 outputs the difference of two integers: the number coming in on the left inlet minus 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.

```

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

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

typedef struct _diff // Data structure for this object
{
    t_object d_ob;    // Must always be the first field; used by Max
    long d_valleft;    // Last value from left outlet
    long d_valright;    // Last value from right outlet
    long d_valtotal;    // Value to be sent to outlet
    void *d_out;    // Pointer to outlet, need one for each outlet
} t_diff;

// Prototypes for methods: you need a method for each message you want to respond to
void *diff_new(long value);    // Object creation method
void diff_int(t_diff *diff, long value); // Method for message "int" in left inlet
void diff_inl(t_diff *diff, long value); // Method for message "int" in right inlet
void diff_bang(t_diff *diff);    // Method for bang message

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

    addbang((method)diff_bang);    // bind method "diff_bang" to the "bang" message
    addint((method)diff_int);    // bind method "diff_int" to int's received in the left inlet
    addinx((method)diff_inl,1);    // bind method "diff_inl" to int's received in the right inlet
}

/*****
diff_new(long value)

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

void *diff_new(long value)
{
    t_diff *diff;

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

```

```

diff->d_valright = value; // Initialize the difference value
diff->d_valleft = 0;
diff->d_valtotal = value;

diff->d_out = intout(diff); // Create our outlet

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

return(diff);             // Must return a pointer to the new instance
}
/*****
diff_int(t_diff *a, long value)

inputs:      diff - pointer to t_diff object
            value - value received in the inlet
description: subtracts 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 diff_int(t_diff *diff, long value)
{
    diff->d_valleft = value; // Store the value received in the left inlet

    diff->d_valtotal = diff->d_valleft - diff->d_valright; // Subtracts the right inlet
                                                         // value from the left

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

/*****
diff_inl(t_diff *diff, long value)

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

void diff_inl(t_diff *diff, long value)
{
    diff->d_valright = value; // Store the value

    diff->d_valtotal = diff->d_valleft - value; // Update new difference
}

/*****
diff_bang(t_diff *a)

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

void diff_bang(t_diff *diff)
{
    outlet_int(diff->d_out, diff->d_valtotal); // put out the current total
}

```

Figure 2. Source code for the diff object

The **diff** object: Initialization

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

```
typedef struct _diff // Data structure for this object
{
    t_object d_ob; // Must always be the first field; used by Max
    long d_valleft; // Last value sent to left outlet
    long d_valright; // Last value sent to right outlet
    long d_valtotal; // Value to be sent to outlet
    void *d_out; // Pointer to outlet, need one for each outlet
} t_diff;
```

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

```
setup((t_messlist **) &this_class, diff_new, 0L, (short)sizeof(t_diff), 0L, A_DEFLONG, 0);
```

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

```
addbang((method)diff_bang); // bind "diff_bang" to the "bang" message
addint((method)diff_int); // bind "diff_int" to int received in the left inlet
addinx((method)diff_inl,1); // bind "diff_inl" to int received in the right inlet
```

The **diff** object: The object creation function

Unlike the **bang** object above, the `diff_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 integer is created, and the right inlet, which accepts integers is also created:

```
void *diff_new(long value)
{
    t_diff *diff;

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

    diff->d_valright = value; // Initialize the diff values
    diff->d_valleft = 0;
    diff->d_valtotal = value;

    diff->d_out = intout(diff); // Create our outlet

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

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

The **diff** object: Methods

The `diff_int` method is called when an integer comes in on the left inlet. It stores the value in `d_valleft`, subtracts that value with `d_valright`, storing the result in `d_valtotal`, then calls the `diff_bang` method to output the result.

```
void *diff_int(t_diff *diff, long value)
{
    diff->d_valleft = value;          // Store the value received in the left inlet
    diff->d_valtotal = diff->d_valleft + diff->d_valright; // Subtract right inlet value
                                                // from the left
    diff_bang(diff);                 // Call bang method right away since it's the left inlet
}
```

The `diff_in1` method is called when an integer comes in on the right inlet. It stores the new value in `d_valright` then updates the `val_total`.

```
void *diff_in1(t_diff *diff, long value)
{
    diff->d_valright = value;          // Store the value
    diff->d_valtotal = diff->d_valleft + value; // Update new total
}
```

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

```
void *diff_bang(t_diff *diff)
{
    outlet_int(diff->d_out, diff->d_valtotal); // simply put out the current total
}
```

The **diff_assist** object: Adding to the Max's New Object list and assistance messages

Two enhancements will be added to the **diff** object: the object (**diff_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 **diff_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", "diff_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", "diff_assist");
```

In order to add the assistance messages, a method must be defined, which must be bound to the Max message "assist". The binding is done in the `main()` as follows:

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

The **diff_assist** object: `diff_assist` method

```
void diff_assist(t_diff *diff, Object *b, long msg, long arg, char *s) // copy the appropriate
message to the destination string
{
    if (msg == ASSIST_INLET) //define ASSIST_INLET (1)
    {
        switch (arg)
        {
            case 0: sprintf(s, "%s", "Left Operand");
                    break;
            case 1: sprintf(s, "%s", "Right Operand");
                    break;
        }
    }
    else if (msg == ASSIST_OUTLET) //define ASSIST_OUTLET (2)
        sprintf(s, "Result");
}
```

In the argument list for **diff_assist**, `diff` 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.

```

/*diff_assist.c -- 97/03/24 IF (based on Dale Stammen's diff)
**                98/01/14 for PowerPC only IF
**                03/09/15 removed the usage of the resource file
**This external object defines an object similar to the standard "-" max object.
**The diff object has 2 inlets and 1 outlet. Left inlet accepts bang and integers,
**right inlet accepts integers, and outlet outputs the difference of the 2 inputs.
*/

#include "ext.h"          // Required for all Max external objects
#include "string.h"
#define ASSIST_INLET (1)
#define ASSIST_OUTLET (2)
void *this_class;        // Required. Global pointing to this class

typedef struct _diff      // Data structure for this object
{
    t_obj d_ob;          // Must always be the first field; used by Max
    long d_valleft;       // Last value sent to left outlet
    long d_valright;      // Last value sent to right outlet
    long d_valtotal;      // Value to be sent to outlet
    void *d_out;          // Pointer to outlet, need one for each outlet
} t_diff;

// Prototypes for methods: you need a method for each message you want to respond to
void *diff_new(long value);          // Object creation method
void diff_int(t_diff *diff, long value); // Method for message "int" in left inlet
void diff_inl(t_diff *diff, long value); // Method for message "int" in right inlet
void diff_bang(t_diff *diff);        // Method for bang message
void diff_assist(t_diff *diff, Object *b, long msg, long arg, char *s); // Assistance method

void main(void)
{
    // set up our class: create a class definition
    setup((t_messlist **) &this_class, (method)diff_new, 0L, (short) sizeof(t_diff), 0L,
        A_DEFLONG, 0);
    addbang((method)diff_bang); // bind method "diff_bang" to the "bang" message
    addint((method)diff_int);   // bind method "diff_int" to int's received in the
                                // left inlet
    addinx((method)diff_inl,1); // bind method "diff_inl" to int's received in the
                                // right inlet
    addmess((method)diff_assist, "assist",A_CANT,0); // bind method "diff_assist" to
                                                    // the assistance message
    finder_addclass("All Objects", "diff_assist"); // add class to the New object list
}

/*****
diff_new(long value)

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

void *diff_new(long value)
{
    t_diff *diff;

    diff = (t_diff *)newobject(this_class); // Create the new instance
    diff->d_valright = value; // Initialize the values
    diff->d_valleft = 0;
    diff->d_valtotal = value;
    diff->d_out = intout(diff); // Create our outlet
    intin(diff,1);             // Create the right inlet
    return(diff);              // Must return a pointer to the new instance
}

```

```

/*****
diff_int(t_diff *a, long value)

inputs:      diff - pointer to t_diff object
             value - value received in the inlet
description: subtracts the right value with the incoming value. Stores the new left inlet
             value as well as the difference and outputs the difference.
returns:     nothing
*****/

void diff_int(t_diff *diff, long value)
{
    diff->d_valleft = value; // Store the value received in the left inlet
    diff->d_valtotal = diff->d_valleft - diff->d_valright; // Subtracts right from the left
    diff_bang(diff); // Call bang method right away since it's the left inlet
}

/*****
diff_inl(t_diff *diff, long value)

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

void diff_inl(t_diff *diff, long value)
{
    diff->d_valright = value; // Store the value
    diff->d_valtotal = diff->d_valleft - value; // Update new difference
}

/*****
diff_bang(t_diff *a)

inputs:      diff -- 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 diff_bang(t_diff *diff)
{
    outlet_int(diff->d_out, diff->d_valtotal); // simply put out the current total
}

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

inputs:      diff - pointer to t_diff object
             b - pointer to the t_diff 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 diff_assist(t_diff *diff, Object *b, long msg, long arg, char *s)
    // copy the appropriate message to the destination string
{
    if (msg == ASSIST_INLET)
    {
        switch (arg)
        {
            case 0: sprintf(s, "%s", "Left Operand");
                    break;
            case 1: sprintf(s, "%s", "Right Operand");
                    break;
        }
    }
}

```

```
    else if (msg == ASSIST_OUTLET)
        sprintf(s, "%s", "Result");
}
```

Figure 3 Source code for diff_assist object

The **absolut** 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;
    t_symbol  *w_sym;
    t_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;
} t_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-checked symbol argument
#define A_OBJ     4 // for argtype lists; passes the value of sym (obsolete)
#define A_DEFLONG 5 // long but defaults to zero
#define A_DEFFLOAT 6 // float, defaults to zero
#define A_DEFSYM  7 // symbol, defaults to ""
#define A_GIMME   8 // request that args be passed as an array
                  // the routine will check the types itself
#define A_CANT    9 // cannot typecheck args
```

One common place where Atom is used is when an argument of an object could be of different data type, e.g. long or float. In the `setup()` function arguments are passed as an array of Atoms (which is the list in Max). The `A_GIMME` is specified in the type argument of the `setup()` function:

```
setup((t_messlist **) &this_class, (method)abs_new, 0L, (short)sizeof(t_abs), 0L,
      A_GIMME, 0);
```

When the instance creation function is called (in this case, `abs_new`), the number of arguments (`ac`) entered and the array of Atoms (`*av`) are passed:

```
void *abs_new(Symbol *s, short ac, t_atom *av)
```

```
/*absolut.c -- 02/10/01 IF
**
** Accepts either integers or floats depending on the argument
** provides assist messages without Resource
*/

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

typedef struct _abs // Data structure for this object
{
    t_object a_ob;    // Must always be the first field; used by Max
    short a_mode;    // Integer or float mode
    void *a_out;      // Pointer to outlet, need one for each outlet
} t_abs;

// Prototypes for methods: you need a method for each message you want to respond to
void *abs_new(Symbol *s, short ac, Atom *av);          // Object creation method
void abs_int(t_abs *abs, long value); // Method for message "int" in left inlet
void abs_flt(t_abs *abs, float value); // Method for message "float" in left inlet

void main(void)
{
    // set up our class: create a class definition
    setup((t_messlist **) &this_class, (method)abs_new, 0L, (short)sizeof(t_abs), 0L,
        A_GIMME, 0);
    addint((method)abs_int); // bind method "abs_int" to int received in the left inlet
    addfloat((method)abs_flt); // bind method "abs_flt" to float received in the left inlet
}

void *abs_new(Symbol *s, short ac, t_atom *av)
{
    t_abs *abs = (t_abs *)newobject(this_class); // Create the new instance
    abs->a_mode = A_LONG; // Initialize the values

    if (ac && av[0].a_type == A_FLOAT)
    {
        abs->a_out = floatout(abs); // Create float outlet
        abs->a_mode = A_FLOAT;
    }
    else
        abs->a_out = intout(abs); // Create int outlet
    return(abs); // Must return a pointer to the new instance
}

void abs_int(t_abs *abs, long value)
{
    if (abs->a_mode == A_LONG)
        outlet_int(abs->a_out, (value >= 0) ? value: -value);
    else
        outlet_float(abs->a_out, (float)((value >= 0) ? value: -value));
}

void abs_flt(t_abs *abs, float value)
{
    if (abs->a_mode == A_LONG)
        outlet_int(abs->a_out, (long)((value >= 0) ? value: -value));
    else
        outlet_float(abs->a_out, (value >= 0) ? value: -value);
}
}
```


The **minium** object: List

A list in Max is simply an array of Atoms. A list will be used if you declare a method that responds to the “list” message and receive its arguments with A_GIMME:

```
address((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 (t_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, t_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).

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 current 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
```

```
/* minimum.c -- output the minimum of a group of numbers ----- */
// The type of output (long or float) is determined by the first number in the argument
// If no argument, it defaults to long
// From the Max 3.5 distribution. Slightly modified by IF 97/04/02
// For PowerPC only 98/01/14 IF
// Minor cleanup 02/09/29 IF
// Topics covered: floats, Atoms, lists

#include "ext.h"

#define MAXSIZE 32

typedef struct minimum
{
    t_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_inl(Minimum *x, long n);
void minimum_float(Minimum *x, double f);
void minimum_ftl(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(void)
{
    setup((t_messlist **)&class, (method)minimum_new, 0L, (short)sizeof(Minimum),
        0L, A_GIMME, 0);
    addbang((method)minimum_bang);
    addint((method)minimum_int);
    addinx((method)minimum_inl, 1);
    addfloat((method)minimum_float);
    addftx((method)minimum_ftl, 1);
    address((method)minimum_list, "list", A_GIMME, 0);
    address((method)minimum_assist, "assist", A_CANT, 0);
    finder_addclass("Arith/Logic/Bitwise", "minimum");
}
```

```

}

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)
{
    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)
{
    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, t_atom *av)
{
    Minimum *x;

    x = (Minimum *)newobject(class);
    x->m_count = 2;
    if (ac)
    {
        x->m_args[1] = *av; // initialize 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 default
    {
        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 `address()` in its main function.

```
address(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:

```
address(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 `address`. For example, to bind the method `atoms_play` with the above message you would write in your main function:

```
address(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. Type checking 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”.

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 address functions:

```
address(atoms_list,"play",A_GIMME,0); // bind method "atoms_list" to "play" message
address(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 or 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

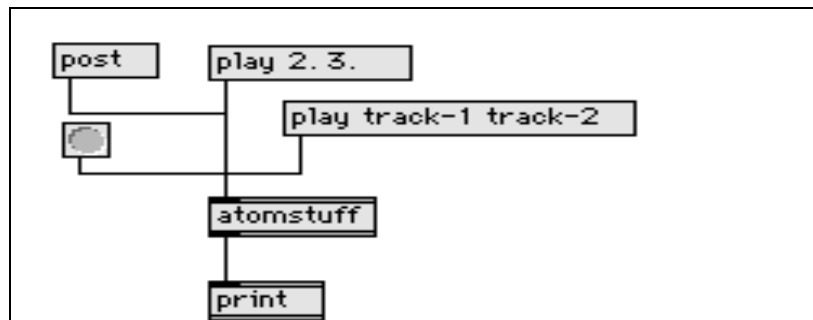
This method receives a list of atoms from Max contain the items of the list sent to your object. The number of items (or atoms) in the list is in `argc`. The actual atoms are stored in `argv`. Actually these are pointers to atoms. We then check each atom for its type before we put it in our list. The 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 with the **Clock** objects allows events to happen in the future. This is accomplished by assigning a function 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_delay()` to schedule the execution of the clock function in the future relative to current time. Use `clock_fdelay()` for floating point version. Use `clock_unset()` to stop the **Clock**.
3. When the **Clock** is no longer needed, it should be removed with `freeobject` function.

```

/* 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 DEFAULT_TEMPO 1000
#define MIN_TEMPO 40

typedef struct _metro /* data structure for this object */
{
    t_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 */
} t_metro;

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

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

void main(void)
{
    /* set up our class: create a class definition */
    setup((t_messlist **) &class, (method)metro_new, (method)metro_free,
          (short)sizeof(t_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 */
address((method)metro_stop,"stop",0);

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

/* 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)
{
    t_metro *m;

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

    if (value > MIN_TEMPO)           // initialize
    {
        m->m_interval = value;       // save tempo argument 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(t_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(t_metro *m, long value)
{
    m->m_interval = value; // store the new metronome interval
    post("metronome tempo changed to %ld", value);
}
}
```

```

/*****
void metro_bang(t_metro *m)

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

    time = gettimeofday(); // get current time
    clock_delay(m->m_clock, 0L); // set clock to go off now
    post("clock started at %ld", time);
}

/*****
void metro_stop(t_metro *m)

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

    time = gettimeofday(); // 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(t_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(t_metro *m)
{
    long time;

    time = gettimeofday(); // 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(t_metro *m)

inputs:    m -- pointer to our object
description: method called when t_metro objects is destroyed. It is used to free memory
            allocated to the clock.
*****/
void metro_free(t_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(t_metro *m, Object *b, long msg, long arg, char *s)
{
    // copy the appropriate message to the destination string
    //assist_string(ResourceID, msg, arg, 1L, 3L, s);
}

```

Figure 6. Source code for mymetro.c

Writing MSP External Objects

Creating a MSP external object is very similar to creating a Max externals. There are two additional methods you need to create: **perform method** and **dsp method**. To create a CodeWarrior project, follow the instruction for Max externals described above using `msp.common.mcp.xml` or `msp.mathlib.mcp.xml` as templates. Or you can simply add the library: `MaxAudioLib.stub` (`c74support/msp-includes/`) into you existing Max project.

An explanation of how to setup an MSP external is given below using a very simple object called **thru~**, which simply outputs the input. (See Figure 7 for the complete source code.)

```

/* thru~.c
** one channel thru object (a minimal MSP object)
** 99/04/05 IF
** 00/02/21 IF mono only, see thru2~ for the stereo version
*/
#include "ext.h"    // Required for all Max external objects
#include "z_dsp.h"  // Required for all MSP external objects

void *thru_class;

typedef struct _thru    // Data structure for this object
{
    t_pxobject x_obj;
} t_thru;

void *thru_new(void);
t_int *thru_perform(t_int *w);
void thru_dsp(t_thru *x, t_signal **sp, short *count);

void main(void)
{
    setup((t_messlist **)&thru_class, (method)thru_new, (method)dsp_free,
          (short)sizeof(t_thru), 0L, 0);
    address((method)thru_dsp, "dsp", A_CANT, 0);
    dsp_initclass();
}

void *thru_new(void)
{
    t_thru *x = (t_thru *)newobject(thru_class);
    dsp_setup((t_pxobject *)x, 1);    // left inlet
    outlet_new((t_pxobject *)x, "signal");    // left outlet
    return (x);
}

void thru_dsp(t_thru *x, t_signal **sp, short *count)
{
    post("thru~ inlet: %d outlet: %d", sp[0]->s_vec, sp[1]->s_vec);
    post("thru~ size of buffer: %d", sp[0]->s_n);
    dsp_add(thru_perform, 3, sp[0]->s_vec, sp[1]->s_vec, sp[0]->s_n);
}

t_int *thru_perform(t_int *w)
{
    t_float *inL = (t_float *)w[1];
    t_float *outL = (t_float *)w[2];
    int n = (int)w[3];

```

```

while (n--)
    *outL++ = *inL++;
return (w + 4); // always add one more than the 2nd argument in dsp_add()
}

```

Figure 7. Source code for thru~.c

The **thru~** object: Initialization

In addition to the required “ext.h,” “z_dsp.h” must be included. z_dsp.h and other MSP-specific header files can be found in the **MSP #includes** folder.

```

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

```

The data structure to define a data structure for the MSP object is different from Max objects. The first field in the struct is the `t_pxobject` instead of the `t_object`. The following is the data structure for the **thru~** object:

```

typedef struct _thru // Data structure for this object
{
    t_pxobject x_obj;
} t_thru;

```

A minimum of three functions must be called in the `main()`. The first is the `setup()`, which is same as the call in the Max objects, except that `dsp_free` must be passed as parameter to free memory. The message binding function, `address()` is called to bind the system message “dsp” to your dsp method, which will add your perform method to the DSP chain. The message “dsp” is sent to your object whenever the user starts DAC or ADC. Finally, `dsp_initclass()` is called to transparently add other methods to your object. As in Max objects, if there are other messages to be bound, it should be done here.

```

void main(void)
{
    setup((t_messlist **)&thru_class, (method)thru_new, (method)dsp_free,
          (short)sizeof(t_thru), 0L, 0);
    address((method)thru_dsp, "dsp", A_CANT, 0);
    dsp_initclass();
}

```

The **thru~** object: New instance creation

In the instance creation function, `thru_new()`, a new object is created via the `newobject()` function. Inlet that accepts signal data is created by the `dsp_setup()` function. This function must be called even if your object does not have any signal inlet, in which case 0 should be passed as the second parameter. The signal outlets are created using the `outlet_new()` function. Use multiple call to `outlet_new()` to create additional outlets. Non-signal inlets, when there are no signal inlets, can be created using the standard functions (e.g. `intin`, `floatin`, `inlet_new`).

```

void *thru_new(void)

```

```

{
    t_thru *x = (t_thru *)newobject(thru_class);
    dsp_setup((t_pxobject *)x, 1);           // left inlet
    outlet_new((t_pxobject *)x, "signal");   // left outlet
    return (x);
}

```

The **thru~** object: The dsp method

The dsp method will be called via the “dsp” message from MSP when it is building the DSP call chain (when audio is turned on). Your task is to add your perform method to the chain using the `dsp_add()`. When MSP calls this function, it is passed the object, an array containing buffers to inlets and outlets defined, and another array that indicates the number of connections to the inlets and outlets. Note that you must add a perform method even if no inlets and outlets are connected.

```

void thru_dsp(t_thru *x, t_signal **sp, short *count)
{
    dsp_add(thru_perform, 3, sp[0]->s_vec, sp[1]->s_vec, sp[0]->s_n);
}

```

The first parameter in `dsp_add()` is the name of your perform method, the second number indicates the number of arguments in the perform method, followed by the arguments, all of which must be the size of a pointer or a long and appears in your perform method as an array of `t_int`. The second parameter passed to the dsp method, `t_signal **sp`, is an array of pointers to struct `t_signal` (defined in **z_dsp.h**).

```

typedef struct _signal
{
    int s_n;                // number of samples: Signal Vector Size
    t_sample *s_vec;        // pointer to inlet/outlet buffer
    float s_sr;             // sample rate
    struct _signal *s_next;
    struct _signal *s_nextused;
    short s_refcount;
    short s_zero;
} t_signal;

```

The array is ordered left to right for inlets then left to right for outlets.

The **thru~** object: The perform method

The perform method is where the actual signal processing take place. The method is added to the DSP signal chain by the dsp method (see above) and will be repeatedly called as long as the audio is on.

```

t_int *thru_perform(t_int *w)
{
    t_float *inL = (t_float *) (w[1]);
    t_float *outL = (t_float *) (w[2]);
    int n = (int) (w[3]);

    while (n--)
        *outL++ = *inL++;
    return(w + 4); // always add one more than the 2nd argument in dsp_add()
}

```


The parameters passed to the perform method are typically pointers to buffers representing the inlets and outlets, and the size of the buffer, which is usually the Signal Vector Size (DSP Status).

The MSP objects: Summary of events and related functions

As with Max objects, when the user creates the object for the first time, the main() is called once. The *object_new()* function is called every time the object is created. The *object_dsp()* function is called every time the DAC/ADC is started or sometimes when connection to object is changed, which initiates the building of the DSP chain. Finally, the *object_perform()* function is called at every audio interrupt.

The **thru2~** object: Stereo version of **thru~**

Figure 8 is the source code for the thru2~ object, which is the stereo version of the thru~ object with two inlets and two outlets. Note that in the thru2_new(), a flag (x->x_obj.z_misc) is set so that inlet and outlet points to two different memory locations. This, in most cases, is not needed or even desired but used here as an illustration. Among the standard MSP object only fft~/ifft~ and tapout~ set this flag. When this flag is not set, which is the default, the input and output buffer maybe the same.

```

/* thru2~.c -- two channel thru object
** 99/04/05 IF
** 00/02/21 IF set x->x_obj.z_misc
*/
#include "ext.h" // Required for all Max external objects
#include "z_dsp.h" // Required for all MSP external objects

void *thru2_class;

typedef struct _thru2 // Data structure for this object
{
    t_pxobject x_obj;
} t_thru2;

void *thru2_new(void);
t_int *thru2_perform(t_int *w);
void thru2_dsp(t_thru2 *x, t_signal **sp, short *count);

void main(void)
{
    setup((t_messclass **)&thru2_class, (method)thru2_new, (method)dsp_free,
          (short)sizeof(t_thru2), 0L, 0);
    address((method)thru2_dsp, "dsp", A_CANT, 0);
    dsp_initclass();
}

void *thru2_new(void)
{
    t_thru2 *x = (t_thru2 *)newobject(thru2_class);
    dsp_setup((t_pxobject *)x, 2); // two inlets
    outlet_new((t_pxobject *)x, "signal"); // left outlet
    outlet_new((t_pxobject *)x, "signal"); // right outlet
    x->x_obj.z_misc = Z_NO_INPLACE;
    return (x);
}

```

```
void thru2_dsp(t_thru2 *x, t_signal **sp, short *count)
{
    dsp_add(thru2_perform, 5, sp[0]->s_vec, sp[1]->s_vec, sp[2]->s_vec,
            sp[3]->s_vec, sp[0]->s_n);
}

t_int *thru2_perform(t_int *w)
{
    t_float *inL = (t_float *) (w[1]);
    t_float *inR = (t_float *) (w[2]);
    t_float *outL = (t_float *) (w[3]);
    t_float *outR = (t_float *) (w[4]);
    int n = (int) (w[5]);
    while (n--)
    {
        *outL++ = *inL++;
        *outR++ = *inR++;
    }
    return (w + 6); // always add one more than the 2nd argument in dsp_add()
}
```

Figure 8. Source code for thru2~.c

The **thru2~** object: New instance creation

In the instance creation function, `thru2_new()`, a new object is created with two signal inlets by specifying 2 as the second argument of `dsp_setup()`. Two outlets are created by calling `outlet_new()` twice. As mentioned before the flag `x->x_obj.z_misc` is set (via `Z_NO_INPLACE`, which is defined in `z_proxy.h`) to guarantee that the input buffer and output buffer point to different memory locations.

```
void *thru2_new(void)
{
    t_thru2 *x = (t_thru2 *)newobject(thru2_class);
    dsp_setup((t_pxobject *)x, 2);           // two inlets
    outlet_new((t_pxobject *)x, "signal"); // left outlet
    outlet_new((t_pxobject *)x, "signal"); // right outlet
    x->x_obj.z_misc = Z_NO_INPLACE;
    return (x);
}
```

The **thru2~** object: The dsp method

Because there are two inlets and two outlets five arguments must be passed to the perform method. The ordering of `sp[]` array is inlets left to right then outlets left to right. So that `sp[0]` points to the left inlet, `sp[1]` to the right inlet, `sp[2]` to the right outlet, and `sp[3]` to the left outlet.

```
void thru2_dsp(t_thru2 *x, t_signal **sp, short *count)
{
    dsp_add(thru2_perform, 5, sp[0]->s_vec, sp[1]->s_vec, sp[2]->s_vec,
            sp[3]->s_vec, sp[0]->s_n);
}
```

The **thru2~** object: The perform method

This perform method has two inputs and two outputs.

```
t_int *thru2_perform(t_int *w)
{
    t_float *inL = (t_float *) (w[1]);
    t_float *inR = (t_float *) (w[2]);
    t_float *outL = (t_float *) (w[3]);
    t_float *outR = (t_float *) (w[4]);
    int n = (int) (w[5]);
    while (n--)
    {
        *outL++ = *inL++;
        *outR++ = *inR++;
    }
    return (w + 6); // always add one more than the 2nd argument in dsp_add()
}
```

The **thru0~** object: No op version of **thru2~**

Depending on how you connect objects it may be that the input and output buffers are the same, so you don't actually have to do "anything" to have signals go through an object (see Figure 9). Do not assume that this will always be the case, however.

```

/* thru0~.c
** two channel thru object (absolute minimal MSP object)
** 99/04/05 IF
** 00/02/21 IF see thru2~ for the not-in-place version
*/
#include "ext.h"
#include "z_dsp.h"

void *thru_class;

typedef struct _thru
{
    t_pxobject x_obj;
} t_thru;

void *thru_new(double val);
t_int *thru_perform(t_int *w);
void thru_dsp(t_thru *x, t_signal **sp, short *count);

void main(void)
{
    setup(&thru_class, thru_new, (method)dsp_free, (short)sizeof(t_thru), 0L, 0);
    addmess((method)thru_dsp, "dsp", A_CANT, 0);
    dsp_initclass();
}

void *thru_new(double val)
{
    t_thru *x = (t_thru *)newobject(thru_class);
    dsp_setup((t_pxobject *)x, 2); // two inlets
    outlet_new((t_pxobject *)x, "signal"); // right outlet
    outlet_new((t_pxobject *)x, "signal"); // left outlet
    return (x);
}

void thru_dsp(t_thru *x, t_signal **sp, short *count)
{
    dsp_add(thru_perform, 0);
}

t_int *thru_perform(t_int *w)
{
    return (w + 1);
}

```

Figure 9. Source code for **thru0~.c**

The **thrugain~** object: signal and non-signal inlets and outlets

The **thrugain~** object demonstrates how to combine signal inlets and outlets with non-signal inlets and outlets. The non-signal (bang, int, float, messages) inlets and outlets must appear to the right of signal inlets and outlets. Therefore the order in which the inlets and outlets are created in the new function is strictly obeyed. The non-signal inlet creation methods (initin, floatin) must precede `dsp_setup()` and non-signal outlet creation methods (bangout, intout, floatout, etc.) must precede signal's `outlet_new()` methods.

```

/* thrugain~.c one signal inlet, one float inlet, one signal outlet, one float outlet
**
** 02/11/04 IF
*/
#include "ext.h"    // Required for all Max external objects
#include "z_dsp.h"  // Required for all MSP external objects

void *thrugain_class;

typedef struct _thrugain // Data structure for this object
{
    t_pxobject t_obj;
    t_float t_gain;
    void *t_out; // float outlet
} t_thrugain;

void *thrugain_new(void);
t_int *thrugain_perform(t_int *w);
void thrugain_dsp(t_thrugain *x, t_signal **sp, short *count);
void thrugain_float(t_thrugain *x, t_float val);

void main(void)
{
    setup((t_messlist **)&thrugain_class, (method)thrugain_new, (method)dsp_free,
          (short)sizeof(t_thrugain), 0L, 0);
    address((method)thrugain_dsp, "dsp", A_CANT, 0);
    addftx((method)thrugain_float, 9); // 9 is the maximum, it has to match the number
    dsp_initclass();                  // in floatin()
}

void *thrugain_new(void)
{
    t_thrugain *x = (t_thrugain *)newobject(thrugain_class);
    x->t_gain = 1.0;
    floatin((t_pxobject *)x, 9); // right float inlet
    dsp_setup((t_pxobject *)x, 1); // left signal inlet, must come after floatin
    x->t_out = floatout((t_pxobject *)x); // right float outlet
    outlet_new((t_pxobject *)x, "signal"); // left signal outlet, must come after floatout
    return (x);
}

void thrugain_float(t_thrugain *x, t_float val)
{
    post("Float in: %f", val);
    x->t_gain = val;
    outlet_float(x->t_out, x->t_gain);
}

void thrugain_dsp(t_thrugain *x, t_signal **sp, short *count)
{
    dsp_add(thrugain_perform, 4, sp[0]->s_vec, sp[1]->s_vec, sp[0]->s_n, x);
}

```



```

t_int *thrugain_perform(t_int *w)
{
    t_float *inL = (t_float *) (w[1]);
    t_float *outL = (t_float *) (w[2]);
    int n = (int) (w[3]);
    t_thrugain *x = (t_thrugain *) w[4];
    while (n--)
        *outL++ = x->t_gain * *inL++;

    return (w + 5); // always add one more than the 2nd argument in dsp_add()
}

```

Figure 10. Source code for thrugain~.c

The thrugain1~ object: using left inlet for both signal and non-signal input

The thrugain1~ object demonstrates how to use the left inlet for both signal and non-signal input. The following example also accepts bangs.

```

/* thrugain1n.c one signal/float inlet, one signal outlet, one float outlet
**
** 02/11/05 IF
**/
#include "ext.h" // Required for all Max external objects
#include "z_dsp.h" // Required for all MSP external objects

void *thrugain_class;

typedef struct _thrugain // Data structure for this object
{
    t_pxobject t_obj;
    t_float t_gain;
    void *t_out; // float outlet
} t_thrugain;

void *thrugain_new(void);
t_int *thrugain_perform(t_int *w);
void thrugain_dsp(t_thrugain *x, t_signal **sp, short *count);
void thrugain_float(t_thrugain *x, t_float val);
void thrugain_bang(t_thrugain *x);

void main(void)
{
    setup((t_messlist **)&thrugain_class, (method)thrugain_new, (method)dsp_free,
    (short)sizeof(t_thrugain), 0L, 0);
    addmess((method)thrugain_dsp, "dsp", A_CANT, 0);
    addfloat((method)thrugain_float);
    addbang((method)thrugain_bang);
    dsp_initclass();
}

void *thrugain_new(void)
{
    t_thrugain *x = (t_thrugain *) newobject(thrugain_class);
    x->t_gain = 1.0;
    dsp_setup((t_pxobject *) x, 1); // left signal inlet
    x->t_out = floatout((t_pxobject *) x); // right float outlet
    outlet_new((t_pxobject *) x, "signal"); // left signal outlet, must come after floatout
    return (x);
}

```

```
}
```



```

void thrugain_float(t_thrugain *x, t_float val)
{
    post("Float in: %f", val);
    x->t_gain = val;
    outlet_float(x->t_out, x->t_gain);
}

void thrugain_bang(t_thrugain *x)
{
    post("Bang");
    outlet_float(x->t_out, x->t_gain);
}

void thrugain_dsp(t_thrugain *x, t_signal **sp, short *count)
{
    dsp_add(thrugain_perform, 4, sp[0]->s_vec, sp[1]->s_vec, sp[0]->s_n, x);
}

t_int *thrugain_perform(t_int *w)
{
    t_float *inL = (t_float *) (w[1]);
    t_float *outL = (t_float *) (w[2]);
    int n = (int) (w[3]);
    t_thrugain *x = (t_thrugain *) w[4];
    while (n--)
        *outL++ = x->t_gain * *inL++;

    return (w + 5); // always add one more than the 2nd argument in dsp_add()
}

```

Figure 11. Source code for thrugain1~.c

The **thrugain2~** object: inlets for both signal and non-signal input

The thrugain2~ object is a stereo thru object that accepts float (and bang) input on both inlets. It exploits the proxy nature of the signal inlets.

```

/* thrugai2n~.c two signal/float inlet, two signal outlets, one float outlet
**
** 02/11/05 IF
**/
#include "ext.h" // Required for all Max external objects
#include "z_dsp.h" // Required for all MSP external objects

void *thrugain_class;

typedef struct _thrugain // Data structure for this object
{
    t_pxobject t_obj;
    t_float t_gain;
    void *t_out; // float outlet
} t_thrugain;

void *thrugain_new(void);
t_int *thrugain_perform(t_int *w);
void thrugain_dsp(t_thrugain *x, t_signal **sp, short *count);
void thrugain_float(t_thrugain *x, t_float val);
void thrugain_bang(t_thrugain *x);

```



```

void main(void)
{
    setup((t_messlist **)&thrugain_class, (method)thrugain_new, (method)dsp_free,
(short)sizeof(t_thrugain), 0L, 0);
    addmess((method)thrugain_dsp, "dsp", A_CANT, 0);
    addfloat((method)thrugain_float);
    addbang((method)thrugain_bang);
    dsp_initclass();
}

void *thrugain_new(void)
{
    t_thrugain *x = (t_thrugain *)newobject(thrugain_class);
    x->t_gain = 1.0;
    dsp_setup((t_pxobject *)x, 2);          // left signal inlet
    x->t_out = floatout((t_pxobject *)x);    // right float outlet
    outlet_new((t_pxobject *)x, "signal"); // middle signal outlet, must come after floatout
    outlet_new((t_pxobject *)x, "signal"); // left signal outlet, must come after floatout
    return (x);
}

void thrugain_float(t_thrugain *x, t_float val)
{
    post("Float in: %f", val);
    x->t_gain = val;
    outlet_float(x->t_out, x->t_gain);
}

void thrugain_bang(t_thrugain *x)
{
    post("Bang");
    outlet_float(x->t_out, x->t_gain);
}

void thrugain_dsp(t_thrugain *x, t_signal **sp, short *count)
{
    dsp_add(thrugain_perform, 6, sp[0]->s_vec, sp[1]->s_vec, sp[2]->s_vec, sp[3]->s_vec, sp[0]-
>s_n, x);
}

t_int *thrugain_perform(t_int *w)
{
    t_float *inL = (t_float *)w[1];
    t_float *inR = (t_float *)w[2];
    t_float *outL = (t_float *)w[3];
    t_float *outR = (t_float *)w[4];
    int n = (int)w[5];
    t_thrugain *x = (t_thrugain *)w[6];

    while (n--)
    {
        *outL++ = x->t_gain * *inL++;
        *outR++ = x->t_gain * *inR++;
    }

    return (w + 7); // always add one more than the 2nd argument in dsp_add()
}

```

Figure 12. Source code for thrugain2~.c