

---

# **microblx Documentation**

**Markus Klotzbuecher et al**

**Jun 10, 2020**



---

## Contents:

---

<b>1</b>	<b>Installing</b>	<b>1</b>
1.1	Building from source . . . . .	1
1.2	Using yocto . . . . .	2
<b>2</b>	<b>Getting started</b>	<b>3</b>
2.1	Microblx in a nutshell . . . . .	3
2.2	Run the threshold example . . . . .	4
2.3	Run the PID controller block . . . . .	5
2.4	Important concepts . . . . .	6
<b>3</b>	<b>Developing microblx blocks</b>	<b>7</b>
3.1	Overview . . . . .	7
3.2	Declaring configuration . . . . .	7
3.3	Declaring ports . . . . .	8
3.4	Declaring block meta-data . . . . .	9
3.5	Declaring/implementing block hook functions . . . . .	9
3.6	Declaring the block . . . . .	12
3.7	Declaring types . . . . .	12
3.8	Block and type registration . . . . .	13
3.9	Using real-time logging . . . . .	14
3.10	SPDX License Identifiers . . . . .	15
3.11	Generating blocks with ubx_genblock . . . . .	15
3.12	Block Interface Guidelines . . . . .	16
3.13	Tips and Tricks . . . . .	16
<b>4</b>	<b>Composing microblx systems</b>	<b>19</b>
4.1	Microblx System Composition DSL (usc files) . . . . .	19
4.2	Hierarchical compositions . . . . .	21
4.3	Model mixins . . . . .	21
4.4	Alternatives . . . . .	22
<b>5</b>	<b>Tutorial: close loop control of a robotic platform</b>	<b>23</b>
5.1	Goal . . . . .	23
5.2	Introductory steps . . . . .	23
5.3	The program . . . . .	31
<b>6</b>	<b>Frequently asked questions</b>	<b>35</b>

6.1	meta-microblx yocto layer: luajit build fails . . . . .	35
6.2	“undefined symbol” errors when loading modules . . . . .	36
6.3	fix “error object is not a string” . . . . .	36
6.4	blockXY.so or liblfd611.so.0: cannot open shared object file: No such file or directory . . .	36
6.5	Real-time priorities . . . . .	36
6.6	My script immediately crashes/finishes . . . . .	36
6.7	Debugging segfaults . . . . .	37
<b>7</b>	<b>Microblx Module Index</b>	<b>39</b>
7.1	Module pid . . . . .	39
7.2	Module luablock . . . . .	40
7.3	Module ramp_double . . . . .	40
7.4	Module rand_double . . . . .	41
7.5	Module math_double . . . . .	41
7.6	Module cconst . . . . .	42
7.7	Module iconst . . . . .	42
7.8	Module ptrig . . . . .	42
7.9	Module trig . . . . .	43
7.10	Module lfd611_cyclic . . . . .	44
7.11	Module hexdump . . . . .	45
7.12	Module mqueue . . . . .	45
<b>8</b>	<b>Indices and tables</b>	<b>47</b>

## 1.1 Building from source

### 1.1.1 Dependencies

Make sure to install the following dependencies

- uthash (apt: uthash-dev)
- autotools etc. (apt: automake, libtool, pkg-config, make)
- cproto (apt: cproto) use by Make to generate prototype header file
- luajit (>=v2.0.0) (apt: luajit and liblua5.1-dev)

The following must be installed from source (see instructions below):

- utils Lua utilities [utils](#) [git](#)
- liblfs lock free data structures (v6.1.1) [liblfs6.1.1](#) [git](#)

Optionally, to run the tests:

- lua-unit (apt: lua-unit, [git](#)) (to run the tests)

### 1.1.2 Building

Before building microblx, liblfs611 needs to be built and installed. There is a set of patches in the microblx repository to clean up the packaging of liblfs. Follow the instructions below:

Clone the code:

```
$ git clone https://github.com/liblfs/liblfs6.1.1.git
$ git clone https://github.com/kmarkus/microblx.git
$ git clone https://github.com/kmarkus/utils.git
```

First build *lfs-6.1.1*:

```
$ cd liblfs6.1.1
$ git am ../microblx/liblfs/*.patch
$ ./bootstrap
$ ./configure
$ make
$ sudo make install
```

Then install *utils*:

```
$ cd ../utils
$ sudo make install
```

Now build *microblx*:

```
$ cd ../microblx
$ ./bootstrap
$ ./configure
$ make
$ sudo make install
```

## 1.2 Using yocto

If you are developing for an embedded system, the recommended way is use the [meta-microblx](#) yocto layer. Please see the README in that repository for further instructions.

### 2.1 Microblx in a nutshell

Building a microblx application typically involves two steps:

#### 2.1.1 Implement the required blocks

define the **block API**

- *configs*: what is (statically) configurable
- *ports*: which data flows in and out of the block

and implement the required block **hooks**

- For example, `init` is typically used to initialize, allocate memory and/or validate configuration.
- the `step` hook implements the “main” functionality and is executed when the block is **triggered**.
- `cleanup` is to “undo” `init` (i.e. free resources etc.)

Take a look at a simple [threshold checking](#) demo block.

---

**Note:** You can examine a block interface using `ubx-modinfo`, e.g. `run $ ubx-modinfo show threshold`.

---

#### 2.1.2 Define the application using a `usc` file

This involves specifying

- which *block instances* to create
- the *configuration* of for each block
- the *connections* to create between ports

- the *triggering* of blocks (i.e. the schedule of when to trigger the step functions of each block)

A small, ready to run usc demo using the *threshold* block is available [here](#)

usc applications can be launched using the *ubx-launch* tool, as shown in the following example.

## 2.2 Run the threshold example

In this small example, a ramp feeds a sine generator whose output is checked whether it exceeds a threshold. The threshold block outputs the current state (1: *above* or 0: *below*) as well as *events* upon passing the threshold. The events are connected to a mqueue block, where they can be logged using the *ubx-mq* tool. The actual composition looks as follows

```
/-----\    /-----\    /-----\    /-----\
| ramp |--->| sin |--->| thres|--->| mq |
\-----/    \-----/    \-----/    \-----/
      ^              ^              ^
      .              . #2          .
#1 .              .              .
      .              /-----\    . #3
      .....| trig |.....
              \-----/

---> depicts data flow
...> means "triggers"
```

Before launching, start a ubx logger client in a separate terminal:

```
$ ubx-log
waiting for rtlog.logshm to appear
```

---

**Note:** The following assumes microblx was installed in the default locations under `/usr/local/`. If you installed it in a different location you will need to adapt the path.

---

Then in a new terminal:

```
$ ubx-launch -loglevel 7 -c /usr/local/share/ubx/examples/usc/threshold.usc
core_prefix: /usr/local
prefixes:    /usr, /usr/local
```

We increase the loglevel to 7 (DEBUG) so that debug messages will be visible. In the log window you should now see “threshold passed” messages.

As the events output by the `thres` block are made available via a mqueue, these can easily be dumped to stdout using `ubx-mq`:

```
$ ubx-mq read threshold_events -p threshold
{ts={nsec=135724534,sec=287814},dir=1}
{ts={nsec=321029297,sec=287814},dir=0}
{ts={nsec=448964856,sec=287815},dir=1}
```

To stop the application again, just type `Ctrl-c` in the `ubx-launch` window.



## 2.3 Run the PID controller block

This more complex example demonstrates how multiple, modular `usc` files can be *composed* into an application and how configuration can be *overlayed*. The use-case is a robot controller composition which shall be used in a test mode (extra mqueue outputs, no real-time priorities) and in regular mode (real-time priorities, no debug outputs).

Before launching, run `ubx-log` as above to see potential errors.

Then:

```
$ cd /usr/local/share/ubx/examples/usc/pid/
$ ubx-launch -webif -c pid_test.usc,ptrig_nrt.usc
merging ptrig_nrt.usc into pid_test.usc
core_prefix: /usr/local
prefixes:    /usr, /usr/local
starting up webinterface block (http://localhost:8888)
loaded request_handler()
```

The `ubx-log` window will show a number messages from the instantiation of the application. The last lines will be about the blocks that were started.

### 2.3.1 Use the webif block

The cmdline arg `-webif` instructed `ubx-launch` to create a web interface block. This block is useful for debugging and introspecting the application. Browser to <http://localhost:8888> and explore:

1. clicking on the node graph will show the connections
2. clicking on blocks will show their interface
3. start the `file_log1` block to enable logging
4. start the `ptrig1` block to start the system.

### 2.3.2 Examining data-flow

The `pid_test.usc` creates several mqueue blocks in order to export internal signals for debugging. They can be accessed using the `ubx-mq` tool:

```
$ ubx-mq list
243b40de92698defa93a145ace0616d2 1    trig_1-tstats
e8cd7da078a86726031ad64f35f5a6c0 10   ramp_des-out
e8cd7da078a86726031ad64f35f5a6c0 10   ramp_msr-out
e8cd7da078a86726031ad64f35f5a6c0 10   controller_pid-out
```

For example to print the `controller_pid-out` signal:

```
ubx-mq read controller_pid-out
{1775781.9200001,1775781.9200001,1775781.9200001,1775781.9200001,1775781.9200001,
↪1775781.9200001,1775781.9200001,1775781.9200001,1775781.9200001,1775781.9200001}
{1776377.9200001,1776377.9200001,1776377.9200001,1776377.9200001,1776377.9200001,
↪1776377.9200001,1776377.9200001,1776377.9200001,1776377.9200001,1776377.9200001}
{1776974.0200001,1776974.0200001,1776974.0200001,1776974.0200001,1776974.0200001,
↪1776974.0200001,1776974.0200001,1776974.0200001,1776974.0200001,1776974.0200001}
{1777570.2200001,1777570.2200001,1777570.2200001,1777570.2200001,1777570.2200001,
↪1777570.2200001,1777570.2200001,1777570.2200001,1777570.2200001,1777570.2200001}
...
```

## 2.4 Important concepts

The following concepts are important to know:

- **modules** are shared libraries that contain blocks or custom types and are loaded when the application is launched.
- a **node** is a run-time container into which *modules* are loaded and which keeps track of blocks etc.
- **types**: microblx essentially uses the C type system (primitive types, structs and arrays of both) for *configs* and data sent via *ports*. To be supported by tools (that is in *usc* files or by tools like *ubx-mq*), custom types must be registered with microblx. The *stdtypes* module contains a large number of common types like *int*, *double*, *stdints* (*int32\_t*) or time handling *ubx\_tstat*.
- **cblocks** vs **iblocks**: there are two types of blocks: *cblocks* (computation blocks) are the “regular” functional blocks with a *step* hooks. In contrast *iblocks* (interaction blocks) are used to implement communication between blocks and implement *read* and *write* hooks. For most applications the available *iblocks* are sufficient, but sometimes creating a custom one can be useful.
- **triggers**: *triggers* are really just *cblocks* with a configuration for specifying a schedule and other properties such as period, thread priority, etc. *ptrig* is the most commonly used trigger which implements a periodic, POSIX pthread based trigger. Sometimes it is useful to implement custom triggers that trigger based on external events. The *trig\_utils* functions (see *.libubx/trig\_utils.h*) make this straightforward.
- **dynamic block interface**: sometimes the type or length of the port data is not static but depends on configuration values themselves. This is almost always the case for *iblocks*

### 3.1 Overview

Generally, building a block entails the following:

1. declaring configuration: what is the static configuration of a block
2. declaring ports: what is the input/output of a block
3. declaring types: which data types are communicated / used as configuration
4. declaring block meta-data: providing further information about a block
5. declaring and implementing hook functions: how is the block initialized, started, run, stopped and cleaned up?
  1. reading configuration values: retrieving and using configuration from inside the block
  2. reading and writing data from resp. to ports
6. declaring the block: how to put everything together
7. registration of blocks and types in module functions: make block prototypes and types known to the system

The following describes these steps in detail and is based on the (heavily) documented random number generator block (`std_blocks/random/`).

---

**Note:** Instead of manually implementing the above, a tool `ubx-genblock` is available which can generate blocks including interfaces from a simple description. See *Generating blocks with `ubx_genblock`*.

---

### 3.2 Declaring configuration

Configuration is described with a `{ 0 }` terminated array of `ubx_config_t` types:

```
ubx_config_t rnd_config[] = {
    { .name="min_max_config", .type_name = "struct random_config" },
    { 0 },
};
```

The above defines a single configuration called `min_max_config` of the type `struct random_config`.

---

**Note:** custom types like `struct random_config` must be registered with the system. (see section [Declaring types](#).) Primitives (`int`, `float`, `uint32_t`, ...) are available from the `stdtypes` module.

---

To reduce boilerplate validation code in blocks, `min` and `max` attributes can be used to define permitted length of configuration values. For example:

```
ubx_config_t rnd_config[] = {
    { .name="min_max_config", .type_name = "struct random_config", .min=1, .max=1 },
    { 0 },
};
```

These specifiers require that this block must be configured with exactly one `struct random_config` value. Checking will take place before the transition to *inactive* (i.e. before `init`).

In fewer cases, configuration takes place in state *inactive* and must be checked before the transition to *active*. That can be achieved by defining the config attribute `CONFIG_ATTR_CHECKLATE`.

Legal values of `min` and `max` are summarized below:

min	max	result
0	0	no checking (disabled)
0	1	optional config
1	1	mandatory config
0	CONFIG_LEN_MAX	zero to many
0	undefined	zero to many
N	M	must be between N and M

### 3.3 Declaring ports

Like configurations, ports are described with a `{ 0 }` terminated array of `ubx_config_t` types:

```
ubx_port_t rnd_ports[] = {
    { .name="seed", .in_type_name="unsigned int" },
    { .name="rnd", .out_type_name="unsigned int" },
    { 0 },
};
```

Depending on whether an `in_type_name`, an `out_type_name` or both are defined, the port will be an in-, out- or a bidirectional port.

### 3.4 Declaring block meta-data

```
char rnd_meta[] =
    "{ doc='A random number generator function block', "
    "  realtime=true, "
    "}";
```

Additional meta-data can be defined as shown above. The following keys are commonly used so far:

- `doc`: short descriptive documentation of the block
- `realtime`: is the block real-time safe, i.e. there are no memory allocation / deallocation and other non deterministic function calls in the `step` function.

### 3.5 Declaring/implementing block hook functions

The following block operations can be implemented to realize the blocks behavior. All are optional.

```
int rnd_init(ubx_block_t *b);
int rnd_start(ubx_block_t *b);
void rnd_stop(ubx_block_t *b);
void rnd_cleanup(ubx_block_t *b);
void rnd_step(ubx_block_t *b);
```

These functions will be called according to the microblx block life-cycle finite state machine:

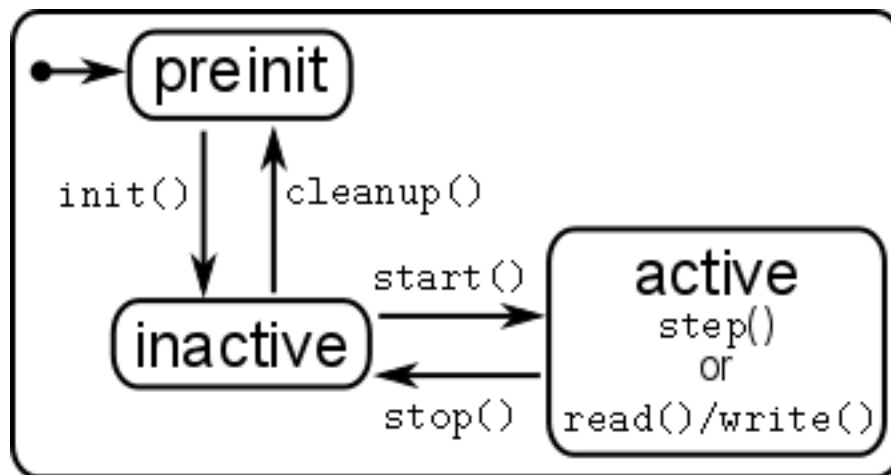


Fig. 1: Block lifecycle FSM

They are typically used for the following:

- `init`: initialize the block, allocate memory, drivers: check if the device exists. Return zero if OK, non-zero otherwise.
- `start`: become operational, open/enable device, carry out last checks. Cache pointers to ports, apply configurations.
- `step`: read from ports, compute, write to ports
- `stop`: stop/close device. stop is often not used.

- cleanup: free all memory, release all resources.

### 3.5.1 Storing block local state

As multiple instances of a block may exist, **NO** global variables may be used to store the state of a block. Instead, the `ubx_block_t` defines a `void* private_data` pointer which can be used to store local information. Allocate this in the init hook:

```
b->private_data = calloc(1, sizeof(struct random_info))

if (b->private_data == NULL) {
    ubx_err(b, "Failed to alloc random_info");
    goto out_err;
}
```

Retrieve and use it in the other hooks:

```
struct block_info *inf;

inf = (struct random_info*) b->private_data;
```

### 3.5.2 Reading configuration values

Configurations can be accessed in a type safe manner using the `cfg_getptr_<TYPE>` family of functions, which are available for all basic types. For example, the following snippet retrieves a scalar `uint32_t` config and uses a default 47 if unconfigured:

```
long len;
uint32_t *value;

if ((len = cfg_getptr_int(b, "myconfig", &value)) < 0)
    goto out_err;

value = (len > 0) ? *value : 47;
```

Defining type safe configuration accessors for custom types can be achieved using the macros described in section *Declaring type safe accessors*.

The following example from the random (`std_blocks/random/random.c`) block shows how this is done for `struct min_max_config`:

```
def_cfg_getptr_fun(cfg_getptr_random_config, struct random_config)

int rnd_start(ubx_block_t *b)
{
    long len;
    const struct random_config* rndconf;

    /*...*/

    /* get and store min_max_config */
    len = cfg_getptr_random_config(b, "min_max_config", &rndconf);

    if (len < 0) {
        ubx_err(b, "failed to retrieve min_max_config");
    }
}
```

(continues on next page)

(continued from previous page)

```

        return -1;
    } else if (len == 0) {
        /* set a default */
        inf->min = 0;
        inf->max = INT_MAX;
    } else {
        inf->min = rndconf->min;
        inf->max = rndconf->max;
    }
}

```

Like with the first example, the the generated accessor `cfg_getptr_random_config` returns `<0` in case of error, `0` if unconfigured, or the array length (`>0`) if configured. If `>0` `rndconf` will be set to point to the actual configuration data.

### Copy configs or use pointer directly?

In the above example, the configuration values are copied to the internal info struct. This is done to be able to assign defaults should no configuration have been given by the user. If this is not required (e.g. for mandatory configurations), it is perfectly OK to use the pointers retrieved via `cfg_getptr:..` functions directly. The following table summarizes the permitted changes in each block state:

block state	allowed config changes
preinit	resizing and changing values
inactive	changing values
active	no changes allowed

Due to possible resizing in *preinit*, config ptr and length should be re-retrieved in *init*.

### When to read configuration: init vs start?

It depends: if needed for initialization (e.g. a char array describing which device file to open), then read in *init*. If it's not needed in *init* (e.g. like the random min-max values in the random block example), then read it in *start*.

This choice affects reconfiguration: in the first case the block has to be reconfigured by a *stop*, *cleanup*, *init*, *start* sequence, while in the latter case only a *stop*, *start* sequence is necessary.

## 3.5.3 Reading from and writing to ports

Writing to ports can be done using the `write_<TYPE>` or `write_<TYPE>_array` functions. For example:

```

/* writing to a port */
unsigned int val = 1;
write_uint(my_outport, &val);

/* reading from a port */
long len;
int val;

len = read_int(my_inport, &val);

```

(continues on next page)

(continued from previous page)

```
if (len < 0)
    ubx_err(b, "port read failed");
    return -1;
else if (len == 0) {
    /* no data on port */
    return 0;
} else {
    ubx_info(b, "new data: %i", val);
}

...
```

For more see `std_blocks/ramp/ramp.c`.

Type safe read/write functions are defined for all basic types and available via the `<ubx.h>` header. Defining similar functions for custom types can be done using the macros described in [Declaring type safe accessors](#).

## 3.6 Declaring the block

The block aggregates all of the previous declarations into a single data-structure that can then be registered in a microblx module:

```
ubx_block_t random_comp = {
    .name = "random/random",
    .type = BLOCK_TYPE_COMPUTATION,
    .meta_data = rnd_meta,
    .configs = rnd_config,
    .ports = rnd_ports,

    /* ops */
    .init = rnd_init,
    .start = rnd_start,
    .step = rnd_step,
    .cleanup = rnd_cleanup,
};
```

## 3.7 Declaring types

All types used for configurations or ports must be declared and registered. This is necessary because microblx needs to know the size of the transported data. Moreover, it enables type reflection which is used by logging or the webinterface.

In the random block example, we used a struct `random_config`, that is defined in `types/random_config.h`:

```
struct random_config {
    int min;
    int max;
};
```

It can be declared as follows:



```
#include "types/random_config.h"
#include "types/random_config.hexarr"
ubx_type_t random_config_type = def_struct_type(struct random_config, &random_config_
↪h);
```

This fills in a `ubx_type_t` data structure called `random_config_type`, which stores information on types. Using this type declaration the `struct random_config` can then be registered with a node (see “Block and type registration” below).

### 3.7.1 Declaring type safe accessors

The following macros are available to define type safe accessors for accessing configuration and reading/writing from ports:

```
def_type_accessors(SUFFIX, TYPENAME)

/* will define the following functions */
long read_SUFFIX(const ubx_port_t* p, TYPENAME* val);
int write_SUFFIX(const ubx_port_t* p, const TYPENAME* val);
long read_SUFFIX_array(const ubx_port_t* p, TYPENAME* val, const int len);
int write_SUFFIX_array(const ubx_port_t* p, const TYPENAME* val, const int len);
long cfg_getptr_SUFFIX(const ubx_block_t* b, const char* cfg_name, const TYPENAME_
↪**valptr);
```

Using these is strongly recommended for most blocks.

#### Variants:

- `def_port_accessors(SUFFIX, TYPENAME)` will define the port but not the config accessors.
- `def_cfg_getptr_fun(FUNCNAME, TYPENAME)` will only define the config accessor
- `def_port_writers(FUNCNAME, TYPENAME)` and `def_port_readers(FUNCNAME, TYPENAME)` will only define the port write or read accessors respectively.

### 3.7.2 What is this .hexarr file

The file `types/random_config.h.hexarr` contains the contents of the file `types/random_config.h` converted to an array `const char random_config_h []` using the tool `tools/ubx-tocarr`. This char array is stored in the `ubx_type_t private_data` field (the third argument to the `def_struct_type` macro). At runtime, this type model is loaded into the luajit ffi, thereby enabling type reflection features such as logging or changing configuration values via the webinterface. The conversion from `.h` to `.hexarray` is done via a simple Makefile rule.

This feature is very useful but optional. If no type reflection is needed, don’t include the `.hexarr` file and pass `NULL` as a third argument to `def_struct_type`.

## 3.8 Block and type registration

So far we have *declared* blocks and types. To make them known to the system, these need to be *registered* when the respective *module* is loaded in a microblx node. This is done in the module *init* function, which is called when a module is loaded:

```
1: static int rnd_module_init(ubx_node_info_t* ni)
2: {
3:     ubx_type_register(ni, &random_config_type);
4:     return ubx_block_register(ni, &random_comp);
5: }
6: UBX_MODULE_INIT(rnd_module_init)
```

Line 3 and 4 register the type and block respectively. Line 6 tells microblx that `rnd_module_init` is the module's init function.

Likewise, the module's cleanup function should deregister all types and blocks registered in init:

```
static void rnd_module_cleanup(ubx_node_info_t *ni)
{
    ubx_type_unregister(ni, "struct random_config");
    ubx_block_unregister(ni, "random/random");
}
UBX_MODULE_CLEANUP(rnd_module_cleanup)
```

## 3.9 Using real-time logging

Microblx provides logging infrastructure with loglevels similar to the Linux Kernel. Loglevel can be set on the (global) node level (e.g. by passing it `-loglevel N` to `ubx-launch` or be overridden on a per block basis. To do the latter, a block must define and configure a `loglevel` config of type `int`. If it is left unconfigured, again the node loglevel will be used.

The following loglevels are supported:

- `UBX_LOGLEVEL_EMERG` (0) (system unusable)
- `UBX_LOGLEVEL_ALERT` (1) (immediate action required)
- `UBX_LOGLEVEL_CRIT` (2) (critical)
- `UBX_LOGLEVEL_ERROR` (3) (error)
- `UBX_LOGLEVEL_WARN` (4) (warning conditions)
- `UBX_LOGLEVEL_NOTICE` (5) (normal but significant)
- `UBX_LOGLEVEL_INFO` (6) (info message)
- `UBX_LOGLEVEL_DEBUG` (7) (debug messages)

The following macros are available for logging from within blocks:

```
ubx_emerg(b, fmt, ...)
ubx_alert(b, fmt, ...)
ubx_crit(b, fmt, ...)
ubx_err(b, fmt, ...)
ubx_warn(b, fmt, ...)
ubx_notice(b, fmt, ...)
ubx_info(b, fmt, ...)
ubx_debug(b, fmt, ...)
```

Note that `ubx_debug` will only be logged if `UBX_DEBUG` is defined in the respective block and otherwise compiled out without any overhead.

To view the log messages, you need to run the `ubx-log` tool in a separate window.

**Important:** The maximum total log message length (including is by default set to 120 by default), so make sure to keep log message short and sweet (or increase the length for your build).

Note that the old (non-rt) macros `ERR`, `ERR2`, `MSG` and `DBG` are deprecated and shall not be used anymore.

Outside of the block context, (e.g. in `module_init` or `module_cleanup`, you can log with the lowlevel function

```
ubx_log(int level, ubx_node_info_t *ni, const char* src, const char* fmt, ...)

/* for example */
ubx_log(UBX_LOGLEVEL_ERROR, ni, __FUNCTION__, "error %u", x);
```

The ubx core uses the same logger mechanism, but uses the `log_info` resp. `logf_info` variants. See `libubx/ubx.c` for examples.

## 3.10 SPDX License Identifiers

Microblx uses a macro to define module licenses in a form that is both machine readable and available at runtime:

```
UBX_MODULE_LICENSE_SPDX(MPL-2.0)
```

To dual-license a block, write:

```
UBX_MODULE_LICENSE_SPDX(MPL-2.0 BSD-3-Clause)
```

It is strongly recommended to use this macro. The list of licenses can be found on <http://spdx.org/licenses>

## 3.11 Generating blocks with ubx\_genblock

The `ubx-genblock` tool generates a microblx block including a Makefile. After this, only the hook functions need to be implemented in the `.c` file:

Example: generate stubs for a myblock block (see `examples/block_model_example.lua` for the block generator model).

```
$ ubx-genblock -d myblock -c /usr/local/share/ubx/examples/blockmodels/block_model_
→example.lua
    generating myblock/bootstrap
    generating myblock/configure.ac
    generating myblock/Makefile.am
    generating myblock/myblock.h
    generating myblock/myblock.c
    generating myblock/myblock.usc
    generating myblock/types/vector.h
    generating myblock/types/robot_data.h
```

Run `ubx-genblock -h` for full options.

The following files are generated:

- `bootstrap` autoconf bootstrap script
- `configure.ac` autoconf input file
- `Makefile.am` automake input file
- `myblock.h` block interface and module registration code (don't edit)

- `myblock.c` module body (edit and implement functions)
- `myblock.usc` simple microblx system composition file, see below (can be extended)
- `types/vector.h` sample type (edit and fill in struct body)
- `robot_data.h` sample type (edit and fill in struct body)

If the command is run again, only the `.c` file will NOT be regenerated. This can be overridden using the `-force` option.

### 3.11.1 Compile the block

```
$ cd myblock/  
$ ./bootstrap  
$ ./configure  
$ make  
$ make install
```

### 3.11.2 Launch block using ubx-launch

```
$ ubx-ilaunch -webif -c myblock.usc
```

Run `ubx-launch -h` for full options.

Browse to <http://localhost:8888>

## 3.12 Block Interface Guidelines

- use `long` (signed) for ubx type related lengths and sizes. This is sufficiently large and errors can be returned as negative values (example: `cfg_getptr_uint32`).

## 3.13 Tips and Tricks

### 3.13.1 Using C++

See `std_blocks/cppdemo`. If the designated initializer (the struct initialization used in this manual) are used, the block must be compiled with `clang`, because `g++` does not support designated initializers (yet).

### 3.13.2 Avoiding Lua scripting

It is possible to avoid the Lua scripting layer entirely. A small example can be found in `examples/c-only.c`. See also the [tutorial](#) for a more complete example.

### 3.13.3 Speeding up port writing

To speed up port writing, the pointers to ports can be cached in the block info structure. The `ubx-genblock` script automatically takes care of this.

### 3.13.4 What the difference between block types and instances?

To create a block instance, it is cloned from an existing block and the `block->prototype` char pointer set to a newly allocated string holding the protoblocks name.

There's very little difference between prototypes and instances:

- a block type's `prototype (char) ptr` is `NULL`, while an instance's points to a (copy) of the prototype's name.
- Only block instances can be deregistered and freed (`ubx_block_rm`), prototypes must be deregistered (and freed if necessary) by the module's cleanup function.

### 3.13.5 Module visibility

The default Makefile defines `-fvisibility=hidden`, so there's no need to prepend functions and global variables with `static`



---

## Composing microblx systems

---

Building a microblx application typically involves instantiating blocks, configuring and interconnecting their ports and finally starting all blocks. The recommended way to do this is by specifying the system using the microblx composition DSL.

### 4.1 Microblx System Composition DSL (usc files)

usc are declarative descriptions of microblx systems that can be validated and instantiated using the `ubx-launch` tool. A usc model describes one microblx **system**, as illustrated by the following minimal example:

```
local bd = require("blockdiagram")

return bd.system
{
  -- import microblx modules
  imports = {
    "stdtypes", "ptrig", "lfds_cyclic", "myblocks",
  },

  -- describe which blocks to instantiate
  blocks = {
    { name="x1", type="myblocks/x" },
    { name="y1", type="myblocks/y" },
    { name="ptrigl", type="std_triggers/ptrig" },
    ...
  },

  -- connect blocks
  connections = {
    { src="x1.out", tgt="y1.in" },
    { src="y1.out", tgt="x1.in", buffer_len=16 },
  },
}
```

(continues on next page)

(continued from previous page)

```

-- configure blocks
configurations = {
  { name="x1", config = { cfg1="foo", cfg2=33.4 } },
  { name="y1", config = { cfgA={ p=1,z=22.3 }, cfg2=33.4 } },

  -- configure a trigger
  { name="trig1", config = { period = {sec=0, usec=100000 },
                           sched_policy="SCHED_OTHER",
                           sched_priority=0,
                           trig_blocks={
                             -- the #<blockname> directive will
                             -- be resolved to an actual
                             -- reference to the respective
                             -- block once instantiated
                             { b="#x1", num_steps=1, measure=0 },
                             { b="#y1", num_steps=1, measure=0 } } } }
},
}

```

### 4.1.1 Launching

usc files like the above example can be launched using `ubx-launch` tool. Run with `-h` for further information. The following example

```

$ cd /usr/local/share/ubx/examples/usc/pid/
$ ubx-launch -webif -c pid_test.usc,ptrig_nrt.usc
...

```

will launch the given system composition and in addition create and configure a web server block to allow the system to be introspected via browser.

Unless the `-nostart` option is provided, all blocks will be initialized, configured and started. `ubx-launch` handles this in safe way by starting up active blocks after all other blocks (In earlier versions, there was `start` directive to list the blocks to be started, however now this information is obtained by means of the block attributes `BLOCK_ATTR_ACTIVE` and `BLOCK_ATTR_TRIGGER`.)

### 4.1.2 Node configs

Node configs allow to assign the same configuration to multiple blocks. This is useful to avoid repeating global configuration values that are identical for multiple blocks.

The `node_configurations` keyword allows to define one or more named node configurations.

```

node_configurations = {
  global_rnd_conf = {
    type = "struct random_config",
    config = { min=333, max=999 },
  }
}

```

These configurations can then be assigned to multiple blocks:

```

{ name="b1", config = { min_max_config = "&global_rnd_conf" } },
{ name="b2", config = { min_max_config = "&global_rnd_conf" } },

```



Please refer to `examples/systemmodels/node_config_demo.usc` for a full example.

## 4.2 Hierarchical compositions

Using hierarchical composition<sup>1</sup> an application can be composed from other compositions. The motivation is to permit reuse of the individual compositions.

The `subsystems` keyword accepts a list of namespace-subsystem entries:

```
return bd.system {
  import = ...
  subsystems = {
    subsys1 = bd.load("subsys1.usc"),
    subsys2 = bd.load("subsys1.usc"),
  }
}
```

Subsystem elements like *configs* can be accessed by higher levels by adding the subsystem namespace. For example, the following lines override a configuration value of the `blk` block in subsystems `sub11` and `sub11/sub21`:

```
configurations = {
  { name="sub11/blk",      config = { cfgA=1, cfgB=2 } },
  { name="sub11/sub21/blk", config = { cfgA=5, cfgB=6 } },
}
```

Note how the subsystem namespaces prevent name collisions of the two identically names blocks. Similar to configurations, connections can be added among subsystems blocks:

```
connections = {
  { src="sub11/sub21/blk.portX", tgt="sub11/blk.portY" },
},
```

When launched, a hierarchical system is instantiated in a similar way to a non-hierarchical one, however:

- modules are only imported once
- blocks from all hierarchy levels are instantiated, configured and started together, i.e. the hierarchy has no implications on the startup sequence.
- microblx block names use the fully qualified name including the namespace. Therefore, the `#blockname` syntax for resolving block pointers works just the same.
- if multiple configs for the same block exist, only the highest one in the hierarchy will be applied.
- node configs are always global, hence no prefix is required. In case of multiple identically named node configs, the one at the highest level will be selected.

## 4.3 Model mixins

To obtain a reusable composition, it is important to avoid introducing platform specifics such as `ptrig` blocks and their configurations. Instead, passive `trig` blocks can be used to encapsulate the trigger schedule. *ptrig* or similar active blocks can then be added at *launch time* by merging them (encapsulated in an `usc` file) into the primary model by specifying both on the `ubx-launch` command line.

<sup>1</sup> This feature was introduced in the context of the COCORF RobMoSys Integrated Technical Project. Please see [docs/dev/001-blockdiagram-composition.md](#) for background information.

For example, consider the example in `examples/systemmodels/composition`:

```
ubx-launch -webif -c deep_composition.usc,ptrig.usc
```

## 4.4 Alternatives

Although using `usc` model is the preferred approach, there are others way to launch a microblx application:

1. by writing a Lua “deployment script” (e.g. see `examples/trig_rnd_to_hexdump.lua`). This is not recommended under normal circumstances, but can be useful in specific cases such as for building dedicated test tools.
2. by assembling everything in C/C++. This can be useful for deploying a self-contained application. Writing this by hand is somewhat cumbersome (see for instance `examples/C-examples/`) and should be solved by a *usc-to-c* compiler. There have been efforts to build this. Please inquire on the mailing list.

---

## Tutorial: close loop control of a robotic platform

---

### 5.1 Goal

This is a walk-through that shows how to:

1. write, compile and install two blocks:
  - the plant (a two DoF robot that accepts velocity as input, and give the relative position), and
  - The controller, that given as a property the set-point and the gain, computes the desired velocity to be set to the robot.
2. instantiate the blocks via the `ubx-launch` tool, and
3. instantiate the blocks with a c-written program.

All the files can be found in the `examples/platform` folder.

### 5.2 Introductory steps

First of all, we need need to define the interface of and between our two components.

The plant and controller has two ports, that exchange position and velocity, each of dimension two, and some properties (initial position and velocity limits for the plant, gain and setpoint for the controller). These properties are described it two lua files:

The plant, “platform\_2dof.lua”

```
return block
{
    name="platform_2dof",
    license="MIT",
    meta_data="",
    port_cache=true,
```

(continues on next page)

(continued from previous page)

```

    configurations= {
    { name="joint_velocity_limits", type_name="double", len=2 },
    { name="initial_position", type_name="double", len=2 },
    },

    ports = {
    { name="pos", out_type_name="double", out_data_len=2, doc="measured position [m]
↪" },
    { name="desired_vel", in_type_name="double", in_data_len=2, doc="desired_
↪velocity [m/s]" }
    },

    operations = { start=true, stop=true, step=true }
}

```

The controller, “platform\_2dof\_control.lua”

```

return block
{
    name="platform_2dof_control",
    license="MIT",
    meta_data="",
    port_cache=true,

    configurations= {
    { name="gain", type_name="double" },
    { name="target_pos", type_name="double" ,len=2 },
    },

    ports = {
    { name="measured_pos", in_type_name="double", in_data_len=2, doc="measured_
↪position [m]" },
    { name="commanded_vel", out_type_name="double", out_data_len=2, doc="desired_
↪velocity [m/s]" },
    },

    operations = { start=true, stop=true, step=true }
}

```

Let us have these file in a folder (e.g. microblx\_tutorial). from these file we can generate the two blocks using the the following bash commands

```

cd microblx_tutorial
ubx-genblock -c platform_2dof.lua -d platform_2dof
ubx-genblock -c platform_2dof_control.lua -d platform_2dof_control

```

Each command generates a folder with the name specified after the -d with five files. For the plant, we will have:

- configure.ac
- Makefile.am
- platform\_2dof.h
- platform\_2dof.c
- platform\_2dof.usc

The only files we will modify are **platform\_2dof/platform\_2dof.c** and **platform\_2dof\_control/platform\_2dof\_control.c**. ## Code of the blocks The file that is auto-generated gives already some hints on how to approach the programming.

```
#include "platform_2dof.h"

/* define a structure for holding the block local state. By assigning an
 * instance of this struct to the block private_data pointer (see init), this
 * information becomes accessible within the hook functions.
 */
struct platform_2dof_info
{
    /* add custom block local data here */

    /* this is to have fast access to ports for reading and writing, without
     * needing a hash table lookup */
    struct platform_2dof_port_cache ports;
};

/* init */
int platform_2dof_init(ubx_block_t *b)
{
    int ret = -1;
    struct platform_2dof_info *inf;

    /* allocate memory for the block local state */
    if ((inf = calloc(1, sizeof(struct platform_2dof_info)))==NULL) {
        ERR("platform_2dof: failed to alloc memory");
        ret=EOUTOFMEM;
        goto out;
    }
    b->private_data=inf;
    update_port_cache(b, &inf->ports);
    ret=0;
out:
    return ret;
}

/* start */
int platform_2dof_start(ubx_block_t *b)
{
    /* struct platform_2dof_info *inf = (struct platform_2dof_info*) b->private_data;
    ↪ */
    ubx_info(b, "platform_2dof start");
    int ret = 0;
    return ret;
}

/* stop */
void platform_2dof_stop(ubx_block_t *b)
{
    /* struct platform_2dof_info *inf = (struct platform_2dof_info*) b->private_data;
    ↪ */
    ubx_info(b, "platform_2dof stop");
}

/* cleanup */
void platform_2dof_cleanup(ubx_block_t *b)
```

(continues on next page)

(continued from previous page)

```

{
    /* struct platform_2dof_info *inf = (struct platform_2dof_info*) b->private_data;
    ↪ */
    ubx_info(b, "platform_2dof cleanup");
    free(b->private_data);
}

/* step */
void platform_2dof_step(ubx_block_t *b)
{
    /* struct platform_2dof_info *inf = (struct platform_2dof_info*) b->private_data;
    ↪ */
    ubx_info(b, "platform_2dof step");
}

```

We will need then to insert the code indicated by the comments. ### Step 1: insert the state of the robot, and other helper functions At the beginning of the file we insert the following code, to save the state of the robot:

```

struct robot_state {
    double pos[2];
    double vel[2];
    double vel_limit[2];
};

double sign(double x)
{
    if(x > 0) return 1;
    if(x < 0) return -1;
    return 0;
}

struct platform_2dof_info
{
    /* add custom block local data here */
    struct robot_state r_state;
    struct ubx_timespec last_time;
    /* this is to have fast access to ports for reading and writing, without
       * needing a hash table lookup */
    struct platform_2dof_port_cache ports;
};

```

The “last\_time” variable is needed to compute the time passed between two calls of the “platform\_2dof\_step” function.

## 5.2.1 Step 2: Initialization and Start functions

This is the function called when the block is initialized; it allocates memory for the info structure, caches the ports, and initializes the state given the configuration values (these values are given in the “.usc” or main application file).

```

int platform_2dof_init(ubx_block_t *b)
{
    int ret = -1;
    long len;
    struct platform_2dof_info *inf;

```

(continues on next page)

(continued from previous page)

```

double *pos_vec;

/* allocate memory for the block local state */
if ((inf = calloc(1, sizeof(struct platform_2dof_info)))==NULL) {
    ubx_err(b, "platform_2dof: failed to alloc memory");
    ret=EOUTOFMEM;
    goto out;
}
b->private_data=inf;
update_port_cache(b, &inf->ports);

//read configuration - initial position
if ((len = ubx_config_get_data_ptr(b, "initial_position", (void **)&pos_vec)) < 0) {
    ubx_err(b, "platform_2dof: failed to load initial_position");
    goto out;
}
inf->r_state.pos[0]=pos_vec[0];
inf->r_state.pos[1]=pos_vec[1];
if ((len = ubx_config_get_data_ptr(b, "joint_velocity_limits", (void **)&pos_vec)) < 0) {
    ubx_err(b, "platform_2dof: failed to load joint_velocity_limits");
    goto out;
}
//read configuration - max velocity
inf->r_state.vel_limit[0]=pos_vec[0];
inf->r_state.vel_limit[1]=pos_vec[1];

inf->r_state.vel[0]=inf->r_state.vel[1]=0.0;
ret=0;
out:
return ret;
}

```

The function `ubx_config_get_data_ptr(ubx_block_t *b, const char *name, void **ptr)` returns in the pointer passed by reference the address of the required configuration. In this case the function will return “2”, success, the length of the data or “-1”, failure.

For the start function, we only need to initialize the internal timer

```

int platform_2dof_start(ubx_block_t *b)
{
    struct platform_2dof_info *inf = (struct platform_2dof_info*) b->private_data;
    ubx_info(b, "platform_2dof start");
    ubx_gettime(&(inf->last_time));
    int ret = 0;
    return ret;
}

```

### 5.2.2 Step 3: Step function

In the step function, we compute the time since last iteration, read the commanded velocity, integrate to position, and then write position.

```

void platform_2dof_step(ubx_block_t *b)
{

```

(continues on next page)

(continued from previous page)

```

int32_t ret;
double velocity[2];
struct ubx_timespec current_time, difference;
struct platform_2dof_info *inf = (struct platform_2dof_info*) b->private_data;
//compute time from last call
ubx_gettime(&current_time);
ubx_ts_sub(&current_time, &(inf->last_time), &difference);
inf->last_time=current_time;
double time_passed= ubx_ts_to_double(&difference);

//read velocity from port
ret = read_desired_vel_2(inf->ports.desired_vel, &velocity);
if (ret<=0){ //nodata
    velocity[0]=velocity[1]=0.0;
    ubx_err(b, "no velocity data");
}

for (int i=0;i<2;i++){// saturate and integrate velocity
    velocity[i]=fabs(velocity[i])> inf->r_state.vel_limit[i]?_
    ↪sign(velocity[i])*(inf->r_state.vel_limit[i]):velocity[i];
    inf->r_state.pos[i]+=velocity[i]*time_passed;}
//write position in the port
write_pos_2(inf->ports.pos, &(inf->r_state.pos));
}

```

In case there is no value in the port ,an error is signaled, and nominal velocity is set to zero. This will always happens in the first interaction, since the controller did step yet, thus no velocity command is available.

### 5.2.3 Step 4: Stop and clean-up functions

These functions are OK as they are generated, since the only thing we want to take care of is that memory is freed.

### 5.2.4 Final listings of the block

The plant is, *mutatis mutandis*, built following the same rationale, and will be not detailed here. the final code of the plant and the controller can be retrieved here **TODO add link to the code**

### 5.2.5 building of the blocks

In order to build and install the blocks, you must execute the following bash commands in each of the two directories:

```

autoreconf --install
./configure
make
sudo make install

```

see also the quickstart about these. ## Deployment via the usc ( microblx system composition) file. The ubx-genblock commands generates two sample files to run independently each block. We want to run and compose them together, and save the results in a logger file. The composition file **platform\_2dof\_and\_control.usc** is quite self explanatory: It indicates

- which libraries are imported,



- which block (name, type) are created,
- the configuration values of properties.

The code is the following.

```
plat_report_conf = [[{
{ blockname='plat1', portname="pos"},
{ blockname='ctrl1', portname="commanded_vel"}
}]] -- this is a multiline string

return bd.system
{
  imports = {
    "stdtypes",
    "ptrig",
    "lfds_cyclic",
    "logger",
    "platform_2dof",
    "platform_2dof_control",
  },

  blocks = {
    { name="plat1", type="platform_2dof" },
    { name="ctrl1", type="platform_2dof_control" },
    { name="logger_time", type="logging/file_logger" },
    { name="fifo_pos", type="lfds_buffers/cyclic" },
    { name="fifo_vel", type="lfds_buffers/cyclic" },
    { name="ptrig1", type="std_triggers/ptrig" },
  },

  connections = {
    { src="plat1.pos", tgt="fifo_pos" },
    { src="fifo_pos",tgt="ctrl1.measured_pos" },
    { src="ctrl1.commanded_vel",tgt="fifo_vel" },
    { src="fifo_vel", tgt="plat1.desired_vel" },
  },

  configurations = {
    { name="plat1", config = { initial_position={1.1,1}, joint_velocity_limits={0.
↪5,0.5} } },
    { name="ctrl1", config = { gain=0.1, target_pos={4.5,4.5} } },
    { name="fifo_pos", config = { type_name="double", data_len=2, buffer_len=1 } },
    { name="fifo_vel", config = { type_name="double", data_len=2, buffer_len=1 } },
    { name="logger_time", config = { filename="/tmp/platform_time.log",
      separator=",",
      report_conf = timer_report_conf, } },
    { name="ptrig1", config = { period = {sec=1, usec=0 },
      sched_policy="SCHED_OTHER",
      sched_priority=0,
      trig_blocks={ { b="#plat1", num_steps=1, measure=1,
↪},
      { b="#ctrl1", num_steps=1, measure=1 },
      { b="#logger_time", num_steps=1, measure=0 } } } }
  }
}
```

It is worth noticing that configuration types can be arrays (e.g. target\_pos), strings (file\_name and

report\_conf) and structures (period) and vector of structures (trig\_blocks). Types for each property should be checked in source files. Alternatively, the web server can provide insight of the types.

The file is launched with the command

```
ubx-ilaunch -c platform_2dof_and_control.usc
```

or

```
ubx-ilaunch -webif -c platform_2dof_and_control.usc
```

to enable the *web interface* at `localhost:8888`. In order to visualize the data saved by the logger in the `:raw-latex:tmp` folder, consider `kst` or any other program that can visualize a comma-separated-value file. ###Some considerations about the fifos

First of all, consider that each (iblock) fifo can be connected with multiple input and multiple output ports. Consider also, that if multiple out are connected, if one read one data, that data will be consumed and not available for a second port.

The more common use-case is that each inport has its own fifo. If the data that is produced by one output is needed to be read by two or more inports, a fifo per inport is connected to the output. **If you use the DSL, this is automatically done, so you do not have to worry to explicitly instantiate the iblocks. This also happens when adding ports to the logger.**

**TODO insert picture**

##Deployment via c program This example is an extension of the “*c-only.c*”. It will be clear that using the above method is far easier, but in case for some reason we want to eliminate the dependency from *lua*, this example shows that is possible, even if a little burdensome.

First of all, we need to make a package to enable the building. This can be done looking at the structure of the rest of packages.

we will create a folder called *platform\_launch* that contains the following files:

- *main.c*
- *Makefile.am*
- *configure.am* ##setup the build system starting from the build part: *configure.am*:

```
m4_define([package_version_major],[0])
m4_define([package_version_minor],[0])
m4_define([package_version_micro],[0])

AC_INIT([platform_launch], [package_version_major.package_version_minor.package_
↪version_micro])
AM_INIT_AUTOMAKE([foreign -Wall])

# compilers
AC_PROG_CC

PKG_PROG_PKG_CONFIG
PKG_INSTALLDIR

AC_CONFIG_HEADERS([config.h])
AC_CONFIG_MACRO_DIR([m4])

# Check if the `install` program is present
AC_PROG_INSTALL
```

(continues on next page)

(continued from previous page)

```

m4_ifdef([AM_PROG_AR], [AM_PROG_AR])
LT_INIT(disable-static)

PKG_CHECK_MODULES(UBX, ubx0 >= 0.6.0)

PKG_CHECK_VAR([UBX_MODDIR], [ubx0], [UBX_MODDIR])
  AC_MSG_CHECKING([ubx module directory])
  AS_IF([test "x$UBX_MODDIR" = "x"], [
    AC_MSG_FAILURE([Unable to identify ubx module path.])
  ])
AC_MSG_RESULT([$UBX_MODDIR])

AC_CONFIG_FILES([Makefile])
AC_OUTPUT

```

### Makefile.am

```

ubxmoddir = ${UBX_MODDIR}

ACLOCAL_AMFLAGS= -I m4
ubxmod_PROGRAMS = platform_main
platform_main_SOURCES = $(top_srcdir)/libubx/ubx.h main.c
platform_main_CFLAGS = -I${top_srcdir}/libubx @UBX_CFLAGS@
platform_main_LDFLAGS = -module -avoid-version -shared -export-dynamic @UBX_LIBS@ -
↳ldl

```

Here, we specify that the name of the executable is *platform\_main*. It might be possible that, if some custom types are used in the configuration, but are not installed, they must be added to the *CFLAGS*:

```
platform_main_CFLAGS = -I${top_srcdir}/libubx -I path/to/other/headers @UBX_CFLAGS@
```

In order to compile, we will use the same commands as before (we do not need to install).

```

autoreconf --install
./configure
make

```

## 5.3 The program

The main follows the same structure of the .usc file. **### Logging** Microblx uses realtime safe functions for logging. For logging from the scope of a block the functions `ubx_info`, `ubx_info`, *etc* are used. In the main we have to use the functions, `ubx_log`, *e.g.*

```
ubx_log(UBX_LOGLEVEL_ERR, &ni, __func__, "failed to init controll");
```

More info on logging can be found in the [Using real-time logging](#) section. **### Libraries** It start with some include (struct that are needed in configuration) and loading the libraries

```

#include <ubx.h>

#define WEBIF_PORT "8810"
#define DOUBLE_STR "double"
#include "trig_spec.h"

```

(continues on next page)

(continued from previous page)

```

#include "ptrig_period.h"
#define LEN_VEC(a) (sizeof(a)/sizeof(a[0]))
int main()
{
    int len, ret=EXIT_FAILURE;
    ubx_node_info_t ni;
    ubx_block_t *plat1, *controll1, *logger1, *ptrig1, *webif, *fifo_vel, *fifo_pos;
    ubx_data_t *d;

    /* initialize the node */
    ubx_node_init(&ni, "platform_and_control");
    const char *modules[8];
    modules[0]= "/usr/local/lib/ubx/0.6/stdtypes.so";
    modules[1]= "/usr/local/lib/ubx/0.6/ptrig.so";
    modules[2]= "/usr/local/lib/ubx/0.6/platform_2dof.so";
    modules[3]= "/usr/local/lib/ubx/0.6/platform_2dof_control.so";
    modules[4]= "/usr/local/lib/ubx/0.6/webif.so";
    modules[5]= "/usr/local/lib/ubx/0.6/logger.so";
    modules[6]= "/usr/local/lib/ubx/0.6/lfds_cyclic.so";
    /* load modules */
    for (int i=0; i<LEN_VEC(modules);i++)
        if(ubx_module_load(&ni, modules[i]) != 0){
            printf("fail to load %s",modules[i]);
            goto out;
        }
}

```

### 5.3.1 Block instantiation

Then, we instantiate blocks (code for only one, for sake of brevity):

```

if((plat1 = ubx_block_create(&ni, "platform_2dof", "plat1"))==NULL){
    printf("fail to create platform_2dof");
    goto out;
}

```

### 5.3.2 Property configuration

Now we have the more tedious part, that is the configuration. it is necessary to allocate memory with the function `ubx_data_resize`, that takes as argument the data pointer, and the new length. ##### String property:

```

d = ubx_config_get_data(webif, "port");
len = strlen(WEBIF_PORT)+1;
/* resize the char array as necessary and copy the port string */
ubx_data_resize(d, len);
strncpy((char *)d->data, WEBIF_PORT, len);

```

Here the sting is declared with a `#define`, it can be written directly, or with a variable, *e.g.* `char filename[]="/tmp/platform_time.log";`

### Double property:

```
d = ubx_config_get_data(ctrl1, "gain");
ubx_data_resize(d, 1);
*((double*)d->data)=0.12;
```

In this case, memory allocation is done for a scalar (i.e. size 1) . The second line says: consider d->data as a pointer to double, and assign to the pointed memory area the value 0.12. ##### Fixed size array of double:

```
d = ubx_config_get_data(ctrl1, "target_pos");
ubx_data_resize(d, 2);
((double*)d->data)[0]=4.5;
((double*)d->data)[1]=4.52;
```

Same as before, but being a vector, of two elements, the memory allocation is changed accordingly, and data writings needs the index. ##### Structure property: To assign the values to the structure, one option is to make/allocate a local instance of the structure, and then copy it.

```
struct ptrig_period p;
p.sec=1;
p.usec=14;
d=ubx_config_get_data(ptrig1, "period");
ubx_data_resize(d, 1);
*((struct ptrig_period*)d->data)=p;
```

In alternative, we can directly work on the fields of the structure

```
d=ubx_config_get_data(ptrig1, "period");
ubx_data_resize(d, 1);
((struct ptrig_period*)d->data)->sec=1;
((struct ptrig_period*)d->data)->usec=14;
```

### Array of structures:

It combines what we saw for arrays and structures. In the case of the trigger block, we have to configure the order of blocks,

```
d=ubx_config_get_data(ptrig1, "trig_blocks");
len= 3;
ubx_data_resize(d, len);
printf("data size trig blocks: %li\n",d->type->size);
((struct trig_spec*)d->data)[0].b = plat1;//ubx_block_get(&ni, "plat1")
((struct trig_spec*)d->data)[0].num_steps = 1;
((struct trig_spec*)d->data)[0].measure = 0;
((struct trig_spec*)d->data)[1].b = ctrl1;
((struct trig_spec*)d->data)[1].num_steps = 1;
((struct trig_spec*)d->data)[1].measure = 0;
((struct trig_spec*)d->data)[2].b = logger1;
((struct trig_spec*)d->data)[2].num_steps = 1;
((struct trig_spec*)d->data)[2].measure = 0;
```

## 5.3.3 Port connection

To connect we have first to retrieve the ports, and then connect to an **iblock**, the fifos. In the following, we have two inputs and two output ports, that are connected via two fifos:

```
ubx_port_t* plat1_pos=ubx_port_get(plat1,"pos");
ubx_port_t* controll_measured_pos=ubx_port_get(controll,"measured_pos");
ubx_port_t* controll_commanded_vel=ubx_port_get(controll,"commanded_vel");
ubx_port_t* plat1_desired_vel=ubx_port_get(plat1,"desired_vel");

ubx_port_connect_out(plat1_pos,fifo_pos);
ubx_port_connect_in(controll_measured_pos,fifo_pos);
ubx_port_connect_out(controll_commanded_vel,fifo_vel);
ubx_port_connect_in(plat1_desired_vel,fifo_vel);
```

### 5.3.4 Init and Start the blocks

Lastly, we need to init and start all the blocks. For example, for the `controll` iblock:

```
if(ubx_block_init(controll) != 0) {
    ubx_log(UBX_LOGLEVEL_ERR, &ni, __func__, "failed to init controll");
    goto out;
}
if(ubx_block_start(controll) != 0) {
    ubx_log(UBX_LOGLEVEL_ERR, &ni, __func__, "failed to start controll");
    goto out;
}
```

The same applies for all the block.

Once all the block are running, the trigger block will call all the blocks in the given order, so long the main does not terminate. To prevent the main process to terminate, we can insert either a blocking call to terminal input:

```
getchar();
```

or using the `signal.h` library, wait until `CTRL+C` is pressed:

```
sigset_t set;
int sig;

sigemptyset(&set);
sigaddset(&set, SIGINT);
pthread_sigmask(SIG_BLOCK, &set, NULL);
sigwait(&set, &sig);
```

Note that we have to link against pthread library, so the `Makefile.am` has to be modified accordingly:

```
platform_main_LDFLAGS = -module -avoid-version -shared -export-dynamic @UBX_LIBS@ -
↳ldl -lpthread
```

## Frequently asked questions

## 6.1 meta-microblx yocto layer: luajit build fails

luajit fails with the following message:

```
arm-poky-linux-gnueabi-gcc -mfpv=neon -mfloat-abi=hard -mcpu=cortex-a8 -fstack-
↳ protector-strong -D_FORTIFY_SOURCE=2 -Wformat -Wformat-security -Werror=format-
↳ security --sysroot=/build/bbblack-zeus/build/tmp/work/cortexa8hf-neon-poky-linux-
↳ gnueabi/lua5.3/2.0.5+gitAUTOINC+02b521981a-r0/recipe-sysroot -fPIC -Wall -D_
↳ FILE_OFFSET_BITS=64 -D_LARGEFILE_SOURCE -U_FORTIFY_SOURCE -DLUA_ROOT="/usr/" -
↳ DLUA_MULTILIB="/lib/" -fno-stack-protector -O2 -pipe -g -feliminate-unused-debug-
↳ types -fmacro-prefix-map=/build/bbblack-zeus/build/tmp/work/cortexa8hf-neon-poky-
↳ linux-gnueabi/lua5.3/2.0.5+gitAUTOINC+02b521981a-r0=/usr/src/debug/lua5.3/2.0.
↳ 5+gitAUTOINC+02b521981a-r0 -fdebug-prefix-map=/build/bbblack-
↳ zeus/build/tmp/work/cortexa8hf-neon-poky-linux-gnueabi/lua5.3/2.0.
↳ 5+gitAUTOINC+02b521981a-r0=/usr/src/debug/lua5.3/2.0.5+gitAUTOINC+02b521981a-r0
↳ -fdebug-prefix-map=/build/bbblack-zeus/build/tmp/work/cortexa8hf-
↳ neon-poky-linux-gnueabi/lua5.3/2.0.5+gitAUTOINC+02b521981a-r0/recipe-sysroot=
↳ -fdebug-prefix-map=/build/bbblack-zeus/build/tmp/work/cortexa8hf-
↳ neon-poky-linux-gnueabi/lua5.3/2.0.5+gitAUTOINC+02b521981a-r0/recipe-sysroot-
↳ native= -c -o lj_obj_dyn.o lj_obj.c
In file included from /usr/include/bits/errno.h:26,
                 from /usr/include/errno.h:28,
                 from host/buildvm.h:13,
                 from host/buildvm_fold.c:6:
/usr/include/linux/errno.h:1:10: fatal error: asm/errno.h: No such file or directory
  1 | #include <asm/errno.h>
    |           ^~~~~~
compilation terminated.
```

This solution is to install gcc-multilib on the build host.

## 6.2 “undefined symbol” errors when loading modules

Try rerunning `ldconfig` (`sudo ldconfig`). It seems there is an `libtool` issue <https://bugs.debian.org/cgi-bin/bugreport.cgi?bug=684981> that makes this necessary under certain circumstances (?).

## 6.3 fix “error object is not a string”

Note that this has been fixed in commit `be63f6408bd4d`.

This is most of the time happens when the `strict` module being loaded (also indirectly, e.g. via `ubx.lua`) in a `luablock`. It is caused by the C code looking up a non-existing global hook function. Solution: either define all hooks or disable the `strict` module for the `luablock`.

## 6.4 `blockXY.so` or `liblfd611.so.0`: cannot open shared object file: No such file or directory

There seems to be a `bug` in some versions of `libtool` which leads to the `ld` cache not being updated. You can manually fix this by running

```
$ sudo ldconfig
```

Often this means that the location of the shared object file is not in the library search path. If you installed to a non-standard location, try adding it to `LD_LIBRARY_PATH`, e.g.

```
$ export LD_LIBRARY_PATH=/usr/local/lib/
```

It would be better to install stuff in a standard location such as `/usr/local/`.

## 6.5 Real-time priorities

To run with realtime priorities, give the `luajit` binary `cap_sys_nice` capabilities, e.g:

```
$ sudo setcap cap_sys_nice+ep `which luajit`
```

Note that this will grant these capabilities to `luajit` binary in `PATH`. If you don't want to do this system-wide, then specify a different version!

## 6.6 My script immediately crashes/finishes

This can have several reasons:

- You forgot the `-i` option to `luajit`: in that case the script is executed and once completed will immediately exit. The system will be shut down / cleaned up rather roughly.
- You ran the wrong Lua executable (e.g. a standard Lua instead of `luajit`).

If none of this works, see the following topic.



## 6.7 Debugging segfaults

One of the best ways to debug crashes is using gdb and the core dump file:

```
# enable core dumps
$ ulimit -c unlimited
$ gdb luajit
...
(gdb) core-file core
...
(gdb) bt
```

Sometimes, running gdb directly on the processes produces better results than post-mortem coredumps. For example, to run the pid example with gdb attached:

```
$ cd /usr/local/share/ubx/examples/usc/pid
$ gdb luajit --args luajit `which ubx-launch` -c pid_test.usc,ptrig_nrt.usc
GNU gdb (Debian 9.1-2) 9.1
...
Reading symbols from luajit...
(No debugging symbols found in luajit)
(gdb) run
Starting program: /usr/bin/luajit /usr/local/bin/ubx-launch -c pid_test.usc,ptrig_nrt.
↪usc
[Thread debugging using libthread_db enabled]
Using host libthread_db library "/lib/x86_64-linux-gnu/libthread_db.so.1".
merging ptrig_nrt.usc into pid_test.usc
core_prefix: /usr/local
prefixes:    /usr, /usr/local
[New Thread 0x7ffff7871700 (LWP 2831757)]
...
```



## 7.1 Module pid

### 7.1.1 Block pid

**Type:** cblock

**Attributes:**

**Meta-data:** { doc='', realtime=true,}

**License:** BSD-3-Clause

#### Configs

name	type	doc
Kp	double	P-gain (def: 0)
Ki	double	I-gain (def: 0)
Kd	double	D-gain (def: 0)
data_len	long	length of signal array (def: 1)

#### Ports

name	out type	out len	in type	in len	doc
msr			double	1	measured input signal
des			double	1	desired input signal
out	double	1			controller output

## 7.2 Module luablock

### 7.2.1 Block lua/luablock

**Type:** cblock

**Attributes:**

**Meta-data:** { doc='A generic luajit based block', realtime=false,}

**License:** BSD-3-Clause

#### Configs

name	type	doc
lua_file	char	
lua_str	char	
loglevel	int	

#### Ports

name	out type	out len	in type	in len	doc
exec_str	int	1	char	1	

## 7.3 Module ramp\_double

### 7.3.1 Block ramp\_double

**Type:** cblock

**Attributes:**

**Meta-data:** { doc='Ramp generator block', realtime=true,}

**License:** BSD-3-Clause

#### Configs

name	type	doc
start	double	ramp starting value (def 0)
slope	double	rate of change (def: 1)
data_len	long	length of output data (def: 1)

#### Ports

name	out type	out len	in type	in len	doc
out	double	1			ramp generator output

## 7.4 Module rand\_double

### 7.4.1 Block rand\_double

**Type:** cblock

**Attributes:**

**Meta-data:** { doc='double random number generator block', realtime=true, }

**License:** BSD-3-Clause

#### Configs

name	type	doc
seed	long	seed to initialize with

#### Ports

name	out type	out len	in type	in len	doc
out	double	1			rand generator output

## 7.5 Module math\_double

### 7.5.1 Block math\_double

**Type:** cblock

**Attributes:**

**Meta-data:** { doc='mathmetric function block', realtime=true, }

**License:** BSD-3-Clause

#### Configs

name	type	doc
func	char	math function to compute
data_len	long	length of output data (def: 1)
mul	double	optional factor to apply to result of func (def: 1)
add	double	optional offset to apply to result of func (def: 0)

#### Ports

name	out type	out len	in type	in len	doc
x			double	1	math input
y	double	1			math output

## 7.6 Module cconst

### 7.6.1 Block consts/cconst

**Type:** cblock

**Attributes:**

**Meta-data:** { doc='const value c-block', realtime=true }

**License:** BSD-3-Clause

#### Configs

name	type	doc
type_name	char	ubx type name of the value to output
data_len	long	data length of the value to output

## 7.7 Module iconst

### 7.7.1 Block consts/iconst

**Type:** iblock

**Attributes:**

**Meta-data:** { doc='const value i-block', realtime=true }

**License:** BSD-3-Clause

#### Configs

name	type	doc
type_name	char	ubx type name of the value to output
data_len	long	data length of the value to output

## 7.8 Module ptrig

### 7.8.1 Block std\_triggers/ptrig

**Type:** cblock

**Attributes:** trigger, active

**Meta-data:** { doc='pthread based trigger', realtime=true,}

**License:** BSD-3-Clause

## Configs

name	type	doc
period	struct ptrig_period	trigger period in { sec, ns }
stacksize	size_t	stacksize as per pthread_attr_setstacksize(3)
sched_priority	int	pthread priority
sched_policy	char	pthread scheduling policy
affinity	int	list of CPUs to set the pthread CPU affinity to
thread_name	char	thread name (for dbg), default is block name
trig_blocks	struct ubx_trig_spec	specification of blocks to trigger
autostop_steps	int64_t	if set and > 0, block stops itself after X steps
tstats_mode	int	enable timing statistics over all blocks
tstats_profile_path	char	directory to write the timing stats file to
tstats_output_rate	double	throttle output on tstats port
tstats_skip_first	int	skip N steps before acquiring stats
loglevel	int	

## Ports

name	out type	out len	in type	in len	doc
tstats	struct ubx_tstat	1			out port for totals and per block timing statistics
shut-down			int	1	input port for stopping ptrig

## 7.8.2 Types

Table 1: Types

type name	type class	size [B]
struct ptrig_period	struct	16

## 7.9 Module trig

### 7.9.1 Block std\_triggers/trig

**Type:** cblock

**Attributes:** trigger

**Meta-data:** { doc='simple, activity-less trigger', realtime=true, }

**License:** BSD-3-Clause

## Configs

name	type	doc
trig_blocks	struct ubx_trig_spec	list of blocks to trigger
tstats_mode	int	0: off (def), 1: global only, 2: per block
tstats_profile_path	char	directory to write the timing stats file to
tstats_output_rate	double	throttle output on tstats port
tstats_skip_first	int	skip N steps before acquiring stats
loglevel	int	

## Ports

name	out type	out len	in type	in len	doc
tstats	struct ubx_tstat	1			timing statistics (if enabled)

## 7.10 Module Ifds\_cyclic

### 7.10.1 Block Ifds\_buffers/cyclic

**Type:** iblock

**Attributes:**

**Meta-data:** { doc='High performance scalable, lock-free cyclic, buffered in process communication description=[[ This version is stongly typed and should be preferred This microblx iblock is based on based on liblfd ringbuffer (v0.6.1.1) ([www.liblfd.org](http://www.liblfd.org))]], version=0.01, hard\_real\_time=true, }

**License:** BSD-3-Clause

## Configs

name	type	doc
type_name	char	name of registered microblx type to transport
data_len	uint32_t	array length (multiplier) of data (default: 1)
buffer_len	uint32_t	max number of data elements the buffer shall hold
loglevel_overruns	int	loglevel for reporting overflows (default: NOTICE, -1 to disable)

## Ports

name	out type	out len	in type	in len	doc
over-runs	unsigned long	1			Number of buffer overruns. Value is output only upon change.



## 7.11 Module hexdump

### 7.11.1 Block hexdump/hexdump

**Type:** iblock

**Attributes:**

**Meta-data:** { doc='hexdump interaction', realtime=false, }

**License:** BSD-3-Clause

## 7.12 Module mqueue

### 7.12.1 Block mqueue

**Type:** iblock

**Attributes:**

**Meta-data:** { doc='POSIX mqueue interaction', realtime=true, }

**License:** BSD-3-Clause

### Configs

name	type	doc
mq_id	char	mqueue base id
type_name	char	name of registered microblx type to transport
data_len	long	array length (multiplier) of data (default: 1)
buffer_len	long	max number of data elements the buffer shall hold
blocking	uint32_t	enable blocking mode (def: 0)



## CHAPTER 8

---

### Indices and tables

---

- `genindex`
- `modindex`
- `search`