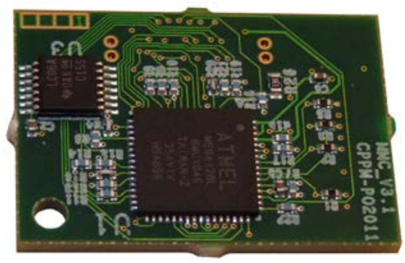
CERN MMC – User Guide

Abstract:

This document describes the CERN Module Management Controller (MMC) features, its use and integration on specific AMC designs. It specifies both Hardware design rules to use the MMC mezzanine and Software customization to fit to AMC requirements.



CERN MMC Mezzanine

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Date: 14/04/2015
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1 Introduction

The CERN MMC (Module Management Controller) is compliant with the Intelligent Platform Management Interface (IPMI) v1.5 standard [1] as well as the PICMG extension for xTCA. The module is implemented as a small mezzanine card to be mounted on AMC modules (Advanced Mezzanine Card). The MMC mezzanine design can also be used as a reference design for direct integration into an AMC project. Development of the MMC software was started by DESY. The original MMC source code was given to CPPM and CERN by Kay Rehlich and Vahan Petrosyan from DESY. The MMC project has then evolved in a joint collaboration between CERN and CPPM and is currently supported by the PH-ESE-BE group at CERN (https://ph-dep-ese.web.cern.ch/ph-dep-ese/).

1.1 MMC role and environment

The MMC communicates with the carrier manager through the IPMB-L bus (I2C based) via the IPMI standard. The module when implemented on an AMC board can be used in both µTCA and/or ATCA environments. Figure 1 bellow shows the Hardware Platform Management components and their connectivity as well as the MMC role and location in an ATCA architecture.

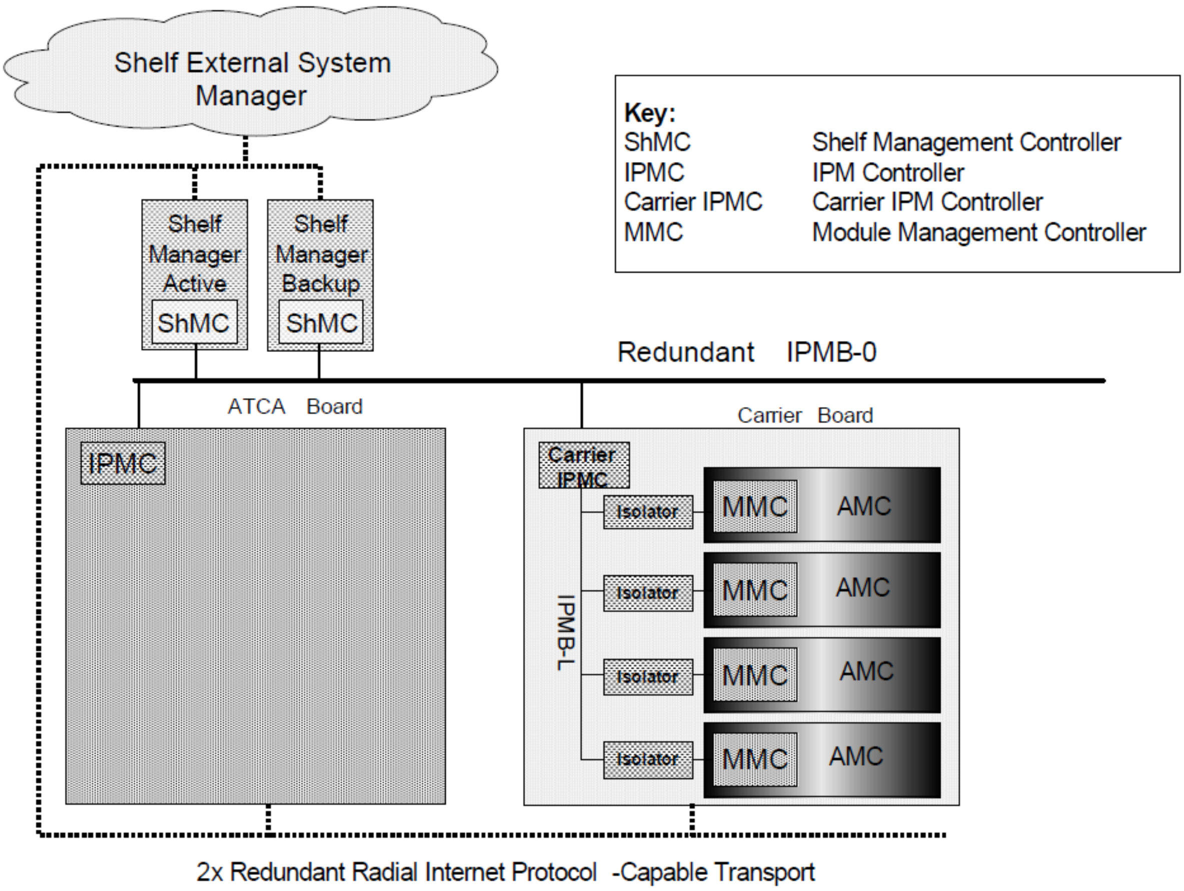


Figure 1: ATCA Hardware Platform Management

In µTCA, the Hardware Platform Management, shown below (Figure 2), is mostly the same. In this architecture, the carrier and shelf managers are both implemented in the MCH (MicroTCA Carrier Hub).

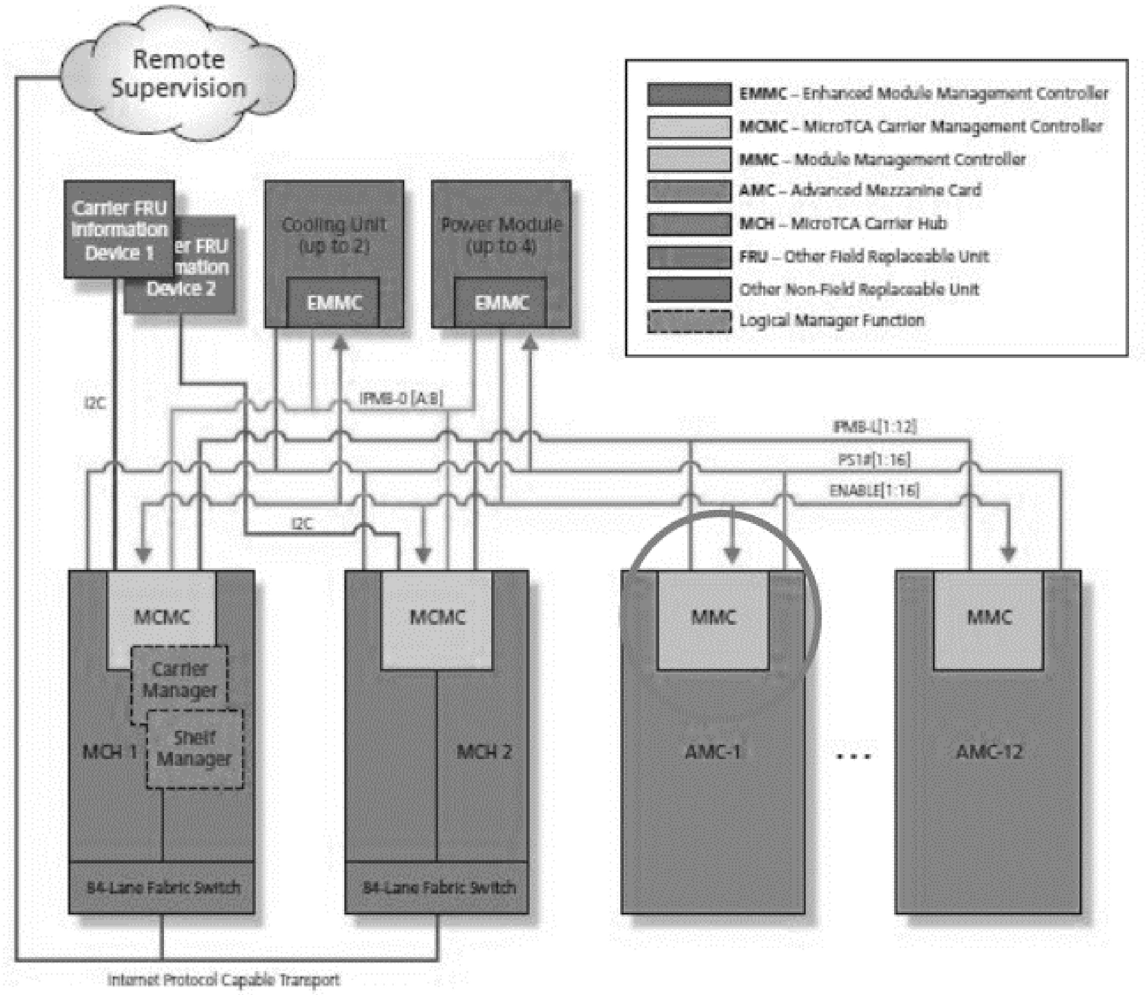


Figure 2: MicroTCA Hardware Platform Management

Upon AMC insertion the MMC provides information like power consumption, ports connectivity, clock configuration, etc. to the carrier IPMC. Based on this information, the carrier IPMC, in association with the Shelf manager, decides whether the AMC can be activated or not. The AMC.0 standard [2] defines an activation/de-activation state machine that handles the AMC hot swapping features. The Figure 3 describes the different states and actions performed during the change of states (AMC activation/de-activation).

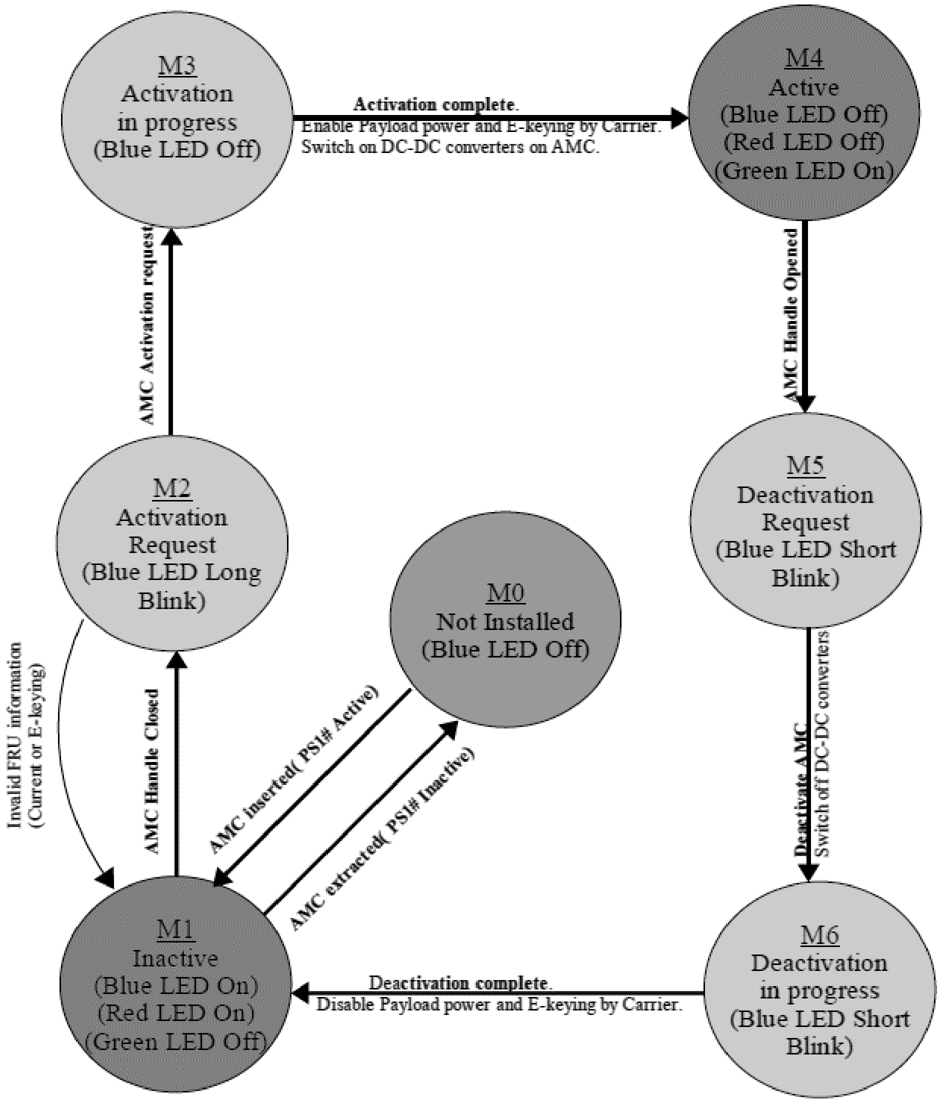


Figure 3: Activation / De-activation state machine

The state machine is managed by the Carrier IPMC. To perform this management task, the carrier manager controller receives handle switch events from the MMC.

The software for the CERN MMC supported features are listed here:

- FRU information (board information, product information, connectivity, …)
- FRU management (hot swap, power, reset, …)
- E-keying
- Clock configuration
- Sensors monitoring (temperatures, voltages, …)
- Hooks for the addition of user functions (OEM support)
- Remote upgrade with HPM.1

2 Setup

This section describes how to install the required development software and tools.

2.1 SVN repository architecture

The MMC project is stored on the following CERN SVN repository server (https://svnweb.cern.ch/cern/wsvn/ph-ese/be/mmc/?#a1c8473bc0300afaf7475ab8f1b9502da).

Note: this directory is restricted to members of the *phese-mmc-users* e-group (https://e-groups.cern.ch/e-groups). Please contact Markus Joos (markus.joos@cern.ch) to request membership.

Note: On Linux systems, the code can be checked out with the command "svn co svn+ssh://svn.cern.ch/reps/ph-ese/be/mmc/"

These is the trunk architecture of the SVN project is given on (Figure 4) below:

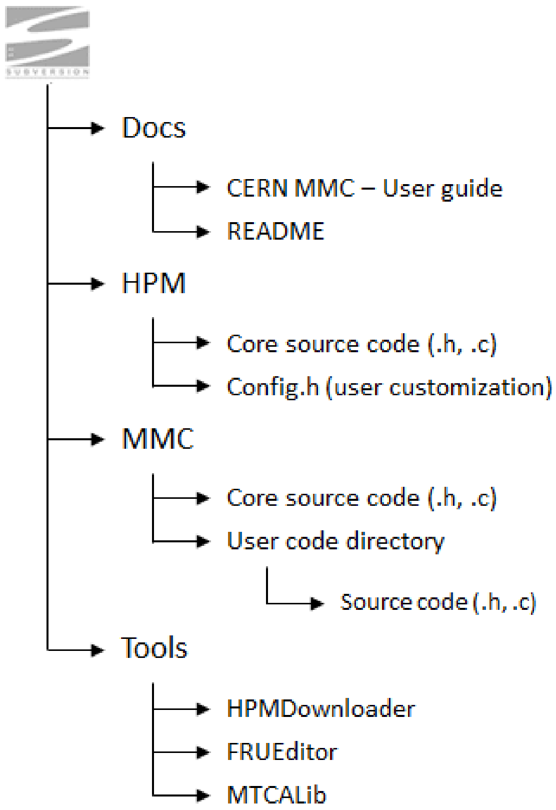


Figure 4: SVN repository architecture

The **Docs directory** contains this document as well as a short README file.

The **HPM directory** contains the HPM project described in chapter 4 of this document.

The ***MMC directory*** contains the MMC application source code composed of the application core and the user directory. The customization of this program is detailed in chapter 5.

The ***Tools directory*** contains 3 tools in relation with the CERN MMC:

- *HPMDownloader*: Allows programming the MMC application using the HPM.1 standard [3]. The procedure is described in section 2.5.
- *FRU Editor*: Generates an FRU information binary from an .h file that can also be used in the MMC application project. One option allows downloading the generated binary into the MMC EEPROM.
- *MTCALib*: C library that allows sending IPMI commands via Ethernet (RMCP) to µTCA modules (MCH, AMC, Cooling units, Power modules).

2.2 Installing the Integrated Development Environment (IDE)

The CERN MMC mezzanine is based on the ATMEGA128 microcontroller from ATMEL. For the compilation of the application, is recommended to use the Atmel Studio IDE (Integrated Development Environment). This environment provides advanced programming and debugging features for MCUs, including the ability to capture data trace information. The latest version of Atmel Studio can be downloaded from the Atmel website (current version: http://www.atmel.com/microsite/atmel_studio6/).

Figure 5: USB driver installation

The USB driver installation must be accepted to use the programmer as described in the next section. After the driver installation, the setup program install the Atmel Studio environment.

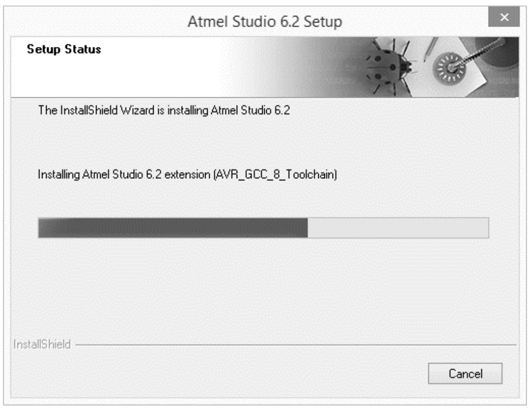


Figure 6: Atmel Studio installation

After successful IDE installation, the CERN_HPM and/or CERN_MMC projects can be opened.

2.3 Downloading the HPM software into the microcontroller

The first programming step consist of downloading the HPM program into the MMC microcontroller flash memory. The CERN_HPM project should be opened (File > Open > Project/Solution and select cern_hpm.atsln) and built before being downloaded into the MMC. The figure below show the Atmel Studio interface after opening the project:

Note: Before compilation, the IANA and product ID must be changed to match with the AMC card it will be installed on. This information is set in the config.h file: the IANA_MANUFACTURER_ID field, which correspond to the IANA manufacturer identification number (http://www.iana.org/assignments/enterprise-numbers) or, and the PRODUCT_ID field, which corresponds to the product identification number. Once these parameters are correctly registered, the project can be built (Build > Build solution)

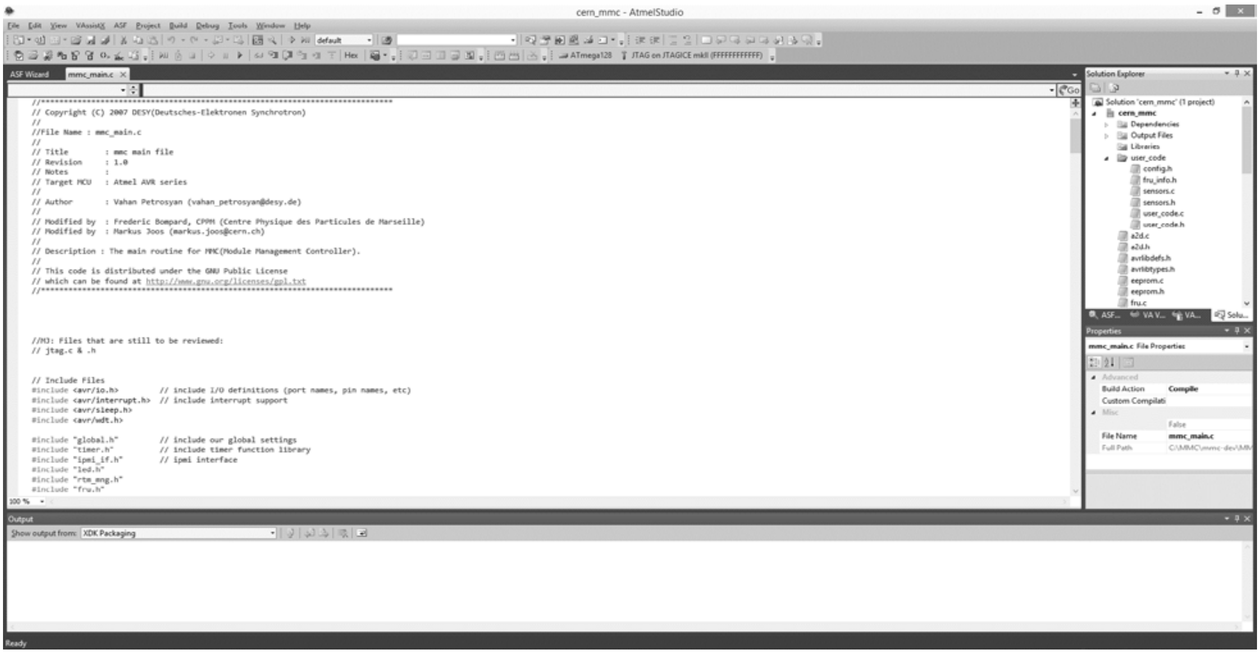


Figure 7: Atmel Studio environment

Before downloading the binary, the microcontroller fuses have to be programmed with the device programming tool (Tools > Device programming) as shown in Figure 8 (Tool selected and Fuses tab):

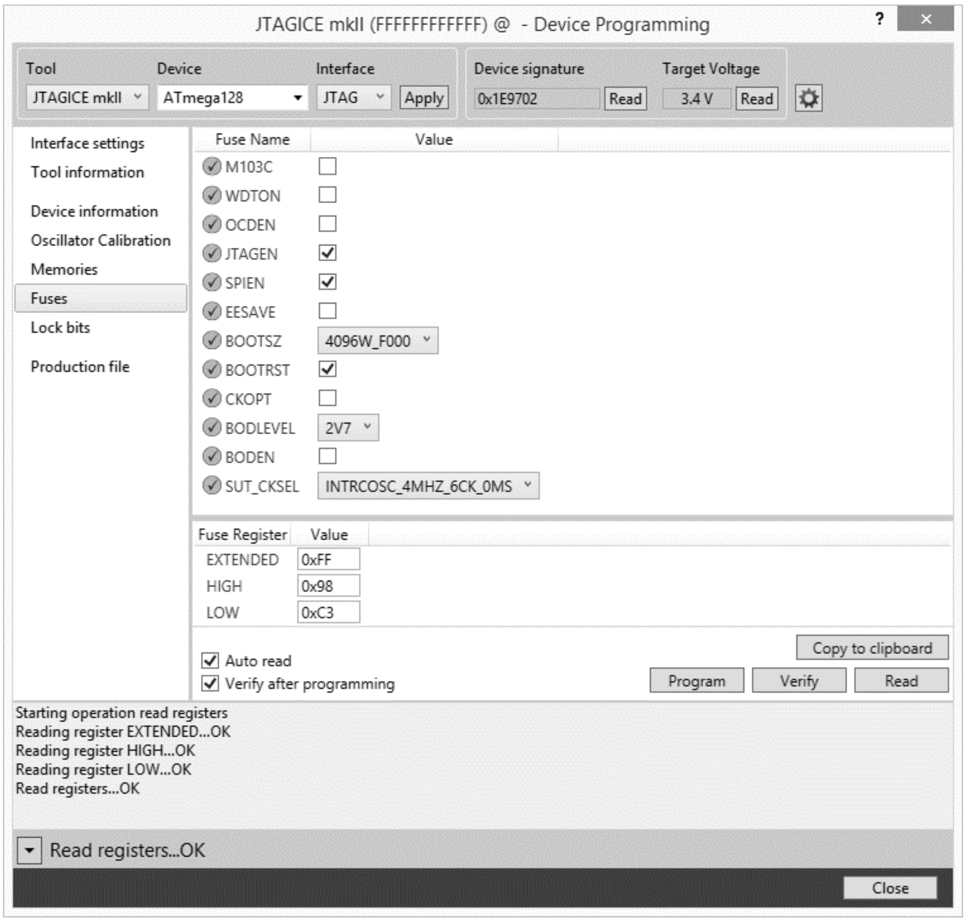


Figure 8: MMC microcontroller fuse configuration

Finally the HPM binary can be downloaded into the microcontroller flash memory (click the "program" button in the Flash box):

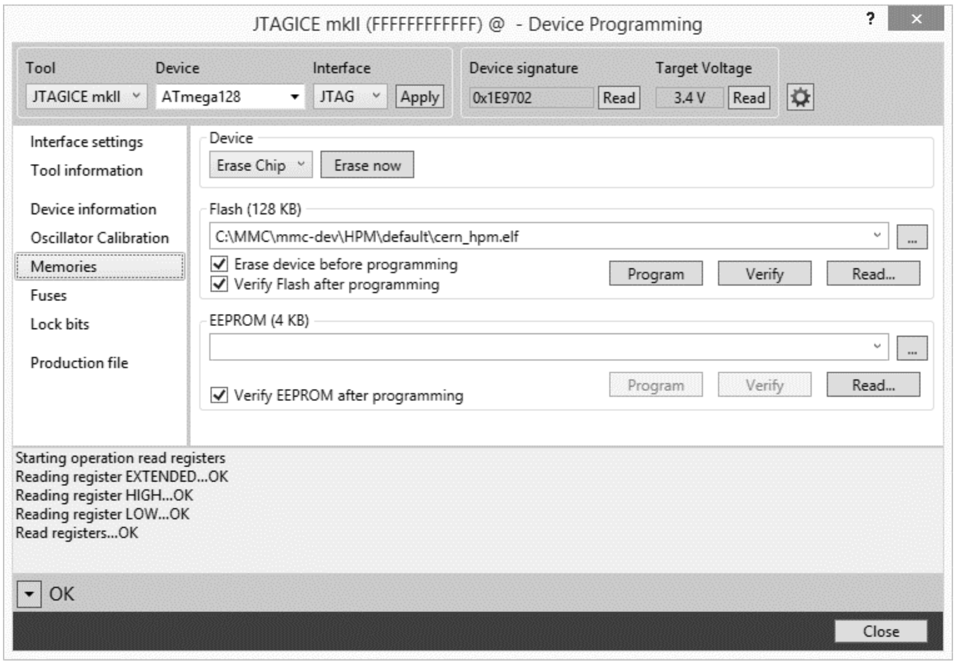


Figure 9: MMC bootloader programming using JTAG

2.4 Downloading/upgrading the MMC application (JTAG)

The MMC application must first be built using Atmel Studio. The cern_mmc project must be opened and can be adapted to fit the specific AMC requirements as detailed in section 5. The binary can be generated (Build > Build solution) from the user code template (default) and downloaded into the MMC (Tools > Device programming) as shown on Figure 10 (Important: The "Erase device before programming" box must not be checked):

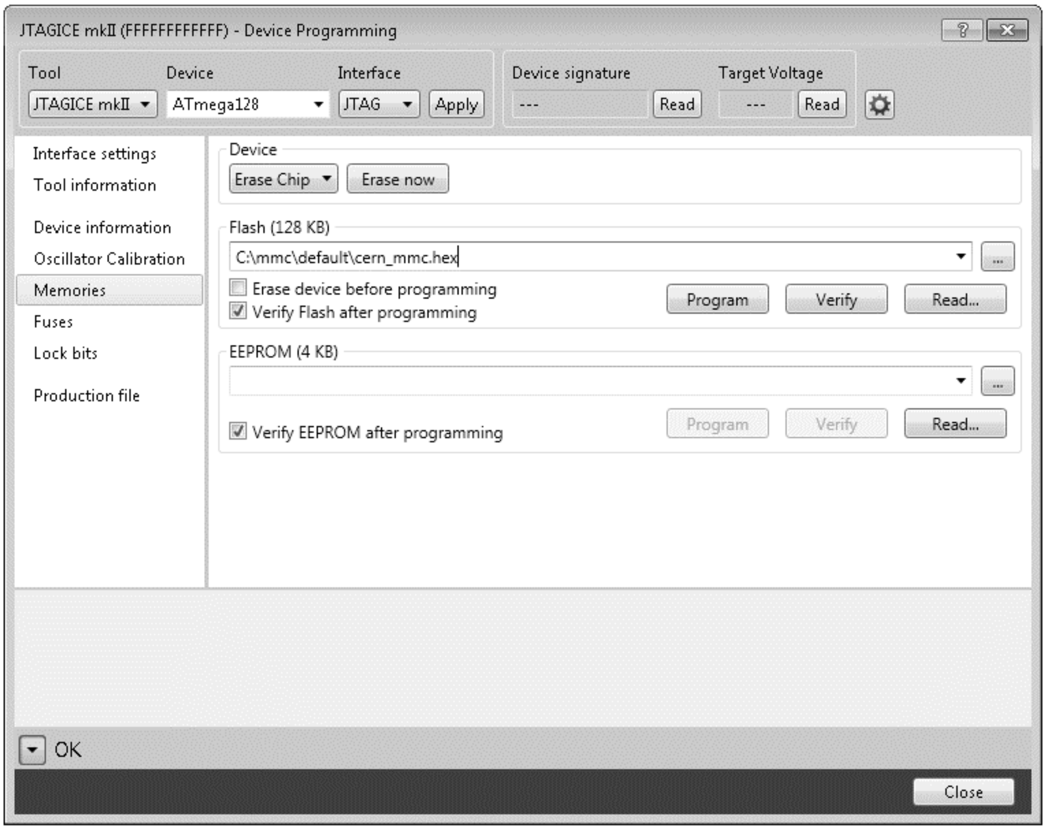


Figure 10: MMC application programming via JTAG

The original user code (template) allows starting the AMC with the default FRU information and power ON/OFF sequence. This template does not implement any custom sensors.

Note: If an uRTM is used with the AMC module, the files present in the user_code directory must be replaced with those present under "user_code (with uRTM)" before compiling. The next section describes how to perform the same action without JTGA (using the HPM.1 feature).

2.5 Downloading/upgrading the MMC application (HPM.1)

The MMC application can be downloaded/upgraded via HPM.1 (download performed via IPMI commands; no JTAG programmer required) with the HPMDownloader program (included in the SVN repository). This software was originally written for Linux and can be used with Cygwin on Windows (The installation procedure is given in Appendix A).

The MMC application must first be built as described in section 2.4. The default/cern_mmc.hex file generated at compilation time will be used to program the MMC. In parallel, the HPMDownloader software must be compiled by executing the make command (using Cygwin or a Linux terminal –

libcrypto and *libssl* are required) from the tool directory. Finally, the MMC Application program can then be downloaded by running the “./hpmdownloader <.hex file>” command, where <.hex file> is the binary generated previously. During execution, some information is requested to create the HPM image used to check the target compatibility. Thus the importance to register the appropriate IANA and product ID numbers as explained in section 2.3 of this document. Below (Figure 11) is an example of MMC programming using the HPMDownloader software:

```
Developped by Julian Mendez <julian.mendez@cern.ch>

  MMC Information
*******************
IANA Manufacturer ID: 0x60
Product ID: 0x1235
Earliest major firware rev. compatible: 1
Earliest minor firware rev. compatible: 0
New major firware rev. compatible: 1
New minor firware rev. compatible: 1

  Download Information
************************
MCH IP: 137.138.63.19
Username: admin
Password: admin
Slot(s) (should be separed by comma - all for all slots): 1

  Downloading firmware
************************
[INFO]   {main}                          Programming MMC slot 1
[INFO]   {Action detected}               Upload firmware image
[INFO]   {Upgrade action detected}       Upgrade for component 0
[INFO]   {Upgrade action detected}       Upgrade to version 10.1
[INFO]   {Upgrade action detected}       "CERN MMC" firmware
[INFO]   {get_img_information}           HPM image check successful
[INFO]   {check_hpm_info}                version 1.0 will be replace by 1.1
[INFO]   {check_hpm_info}                HPM image check successful
[INFO]   {Upgrade in progress}           19776 / 19776
[INFO]   {Upgrade action}                Upgrade success

  Failure report
******************
No failure
```

Figure 11: MMC programming using HPM.1

3 Hardware

3.1 Mezzanine pinout

Pin	Pin name	µC	Description
1	12 Volts	PF0 / ADC[0]	12 volts monitoring
2	GPIO[0] / FPGA nReset	PC2	User / FPGA nReset IO
3	GPIO[1] / FPGA2 Init done	PC4	User / FPGA2 Init done IO
4	GPIO[2] / FPGA nReload	PC3	User / FPGA nReload IO
5	GPIO[3] / FPGA1 Init done	PC5	User / FPGA1 Init done IO
6	Green nLED	PB6	Green LED (AMC front)
7	MMC SCL	PD4	Local I2C bus (SCL)
8	Blue nLED	PB7	Blue LED (Mandatory, AMC front)
9	MMC SDA	PD5	Local I2C bus (SDA)
10	Red nLED	PB5	Red LED (AMC front)
11	Handle switch nCLOSED	PD2	Handle switch input
12	GND		
13	Low voltage POK	PA0	Low voltage failure detection
14	IPMB-L SCL	PD0	IPMB-L bus (SCL)
15	GA1	PB2	Geographical address bit 1
16	IPMB-L SDA	PD1	IPMB-L bus (SDA)
17	GA0	PB1	Geographical address bit 0
18	GPIO[4] / Regulator Enable	PC6	User / Regulator enable IO
19	nPS1	PE2	Present signal (PS1)
20	GPIO[5] / DCDC Enable	PC7	User / DCDC enable IO
21	nPS0	PE3	Present signal (PS0)
22	GA 2	PB3	Geographical address 2
23	GPIO[13] / RTM PS	PA2	User (no RTM) / RTM present signal
24	AMC nENABLE	RESET	AMC enable N signal
25	GPIO[14] / RTM 12 volts enable	PA3	User (no RTM) / RTM 12V enable signal
26	GPIO[6] / ADC[1]	PF1 / ADC[1]	User IO (Optionally Analog 1)
27	GPIO[15] / RTM 3.3 volts enable	PA4	User (no RTM) / RTM 3.3V enable signal
28	GPIO[7] / ADC[2]	PF2 / ADC[2]	User IO (Optionally Analog 2)
29	GND		
30	GPIO[8] / ADC[3]	PF3 / ADC[3]	User / Payload / Analog signal
31	GPIO[16] / RTM I2C Enable	PA5	User (no RTM) / RTM I2C enable signal
32	Master TCK	PG0	Master JTAG (TCK)
33	GPIO[9]	PE6	User / Payload IO
34	Master TMS	PG1	Master JTGA (TMS)
35	GPIO[10]	PE4	User / Payload IO
36	Master TDO	PG2	Master JTAG (TDO)
37	GPIO[11]	PE5	User / Payload IO
38	Local TDI	PG3	Master JTAG (TDI)
39	3.3 Volts		
40	GPIO[12]	PE7	User / Payload IO

Table 1: MMC mezzanine pinout

4 HPM.1

HPM.1 (Hardware Platform Management .1) is a PICMG standard specifying remote firmware upgrade features of IPM Controller (e.g.: MMC). HPM.1 support requires a boot loader program to be downloaded into the microcontroller flash memory to re-write the flash application memory. The HPM directory present in the SVN directory contains the boot loader program for the MMC microcontroller. The MMC microcontroller flash architecture is shown below (Figure 12):

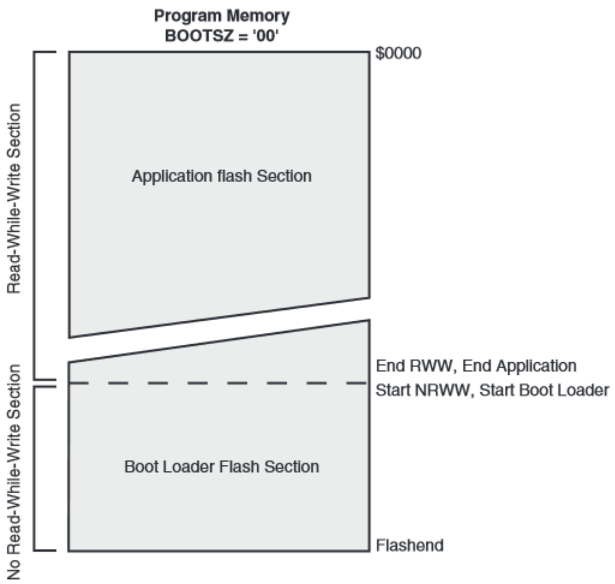


Figure 12: MMC microcontroller flash memory architecture

The Application Flash Section can be erased and written by the boot loader program that contains the HPM project binary. The MMC application is stored in the application flash section. Upon startup, the microcontroller begins at the first boot loader section address with the following algorithm (Figure 13) that decides which of the HPM or MMC application should be executed:

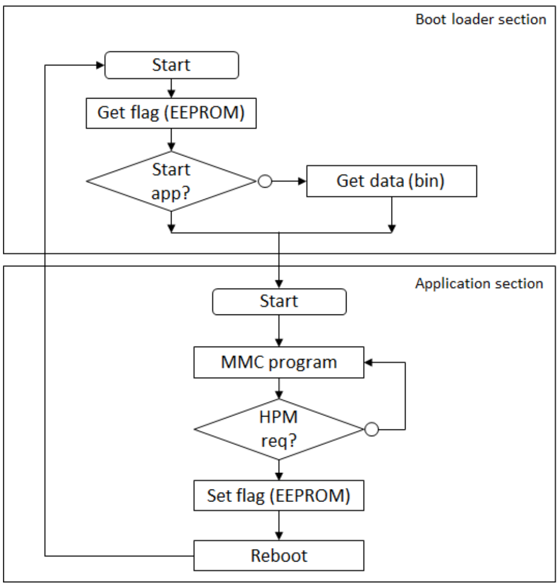


Figure 13: Start-up algorithm

5 MMC Application software

This section describes the features implemented on the CERN MMC as well as how to customize the source code according to the specific AMC project needs and requirements.

5.1 Commands implemented

The table below (Table 2) lists the IPMI commands supported by the MMC program. These commands are specified by the IPMI 1.5 [1] and PICMG ATCA [4]/AMC.0 [2] standards. In addition, OEM commands (NetFN 2Eh) and/or controller specific commands (NetFN 30h) can optionally be implemented by user.

Name	NetFN	Cmd	Description
Get device id	06h	01h	Get device information
Broadcast get device id	06h	01h	Idem, broadcasted to all devices
Set event receiver	04h	00h	Set event register IPMB address
Get event receiver	04h	01h	Get event register IPMB address
Get device SDR info	04h	20h	Get information about SDR
Get device SDR	04h	21h	Read SDR register(s)
Reserve device SDR repo.	04h	22h	Get reservation ID used to read SDR
Get sensor threshold	04h	27h	Get threshold for specified sensor
Get sensor reading	04h	2Dh	Get sensor value (raw)
Get FRU inventory area info	0Ah	10h	Get information about FRU
Read FRU data	0Ah	11h	Read FRU information byte(s)
Write FRU data	0Ah	12h	Write FRU information byte(s)
Get properties	2Ch	00h	Get device properties
FRU control	2Ch	04h	FRU control (reset, reboot …)
Get FRU led properties	2Ch	05h	Get properties of specified LED
Get led colour capabilities	2Ch	06h	Get colour capabilities of specified LED
Set FRU led state	2Ch	07h	Set LED state (ON/OFF, blink, lamp test)
Get FRU led state	2Ch	08h	Get state of specified LED
Get device locator record	2Ch	0Dh	Read device locator record
Set power level	2Ch	11h	Control power level
Set AMC port state	2Ch	19h	Enable/Disable AMC port
Get AMC port state	2Ch	1Ah	Get AMC port state
FRU control capabilities	2Ch	1Eh	Get control capabilities (reboot, reset …)
Set clock state	*2Ch*	*2Ch*	*Foreseen*
Get clock state	*2Ch*	*2Dh*	*Foreseen*

Table 2: IPMI and PICMG commands implemented

The table below (Table 3) lists the HPM commands supported by the CERN MMC.

Name	NetFN	Cmd	Description
Get target upgrade capabilities	2Ch	2Eh	Get upgrade features capabilities
Get component properties	2Ch	2Fh	Get component information (version …)
Initiate upgrade action	2Ch	30h	Start an upgrade action
Upload firmware block	2Ch	32h	Upload firmware binary
Finish firmware upload	2Ch	33h	Check the binary size and finalize the upgrade
Get upgrade status	2Ch	34h	Get information about the ongoing upgrade

Table 3: HPM commands implemented

5.2 User code architecture

The CERN MMC source code is divided into two parts: core and user. In principle, users only need to modify the files present in the user_code directory:

- Config file (config.h):
  - Product information (IANA, Product ID, Firmware version)
  - User IOs configuration
  - Payload sequences (Power ON/OFF, reboot, warm/cold reset)
  - Additional LEDs description
- Fru info file (fru_info.h):
  - FRU information (Language, Generator source information , enabled areas)
  - Board information area (Board name, serial number, product number, …)
  - Product information area (Product name, manufacturer, serial number, …)
  - Point to point connectivity record (E-Keying)
  - Clock configuration record (Clock E-Keying)
  - Module current record (Current limit)
- Sensors files (sensors.h and sensors.c):
  - Header file contains SDR descriptions (**Up to 42 SDRs (40 users + 2 Generic)**)
  - Source code file contains sensor initialisation function
  - Source code file contains sensor monitoring function (polled every 100ms)
- User code files (user_code.c):
  - OEM commands
  - Controller specific commands
  - User main function for bench top use
- E-Keying management file (ekeying.c):
  - AMC port initialization
  - User command for activation/de-activation of AMC port
  - User command for activation/de-activation of AMC clock

5.3 User GPIO

Some microcontroller pins can optionally be used as user defined GPIO. In addition, a few generic pins can have multiple usages as described in section 3.2. The default configuration of these pins corresponds to their main function (E.g.: default configuration of pin PC2 is output as required by the FPGA nReset signal). In any case, all GPIO compatible pins are freely configurable as shown below:

user_code/config.h:

```
/** USER GPIO INITIALIZATION */
//#define GPIO0_DIR          INPUT   //Not defined -> FPGA nRESET config.
//#define GPIO1_DIR          INPUT   //Not defined -> FPGA2 Init done config.
//#define GPIO2_DIR          INPUT   //Not defined -> FPGA nReload config.
//#define GPIO3_DIR          INPUT   //Not defined -> FPGA1 Init done config.
//#define GPIO4_DIR          INPUT   //Not defined -> Regulator Enable config.
//#define GPIO5_DIR          INPUT   //Not defined -> DCDC Enable config.
#define GPIO6_DIR            OUTPUT
#define GPIO7_DIR            OUTPUT
#define GPIO8_DIR            OUTPUT
#define GPIO9_DIR            OUTPUT
#define GPIO10_DIR           OUTPUT
#define GPIO11_DIR           OUTPUT
#define GPIO12_DIR           OUTPUT
```

5.4 Analog to Digital Converter (ADC)

Some microcontroller pins can optionally be used as analogue inputs. By default, these pins are configured as GPIO but can be redefined with the ENABLE_ADC<n> macro (<n> is the identifier of the ADC to be enabled). This configuration overwrites previous GPIO configuration for the dedicated pin. The example below shows how to enable ADC features for pin PF1 and PF2:

```
/** USER ADC INITIALIZATION */
#define ENABLE_ADC1          //ADC[1] is associated with the PF1 pin.
#define ENABLE_ADC2          //ADC[2] is associated with the PF2 pin.
//#define ENABLE_ADC3        //ADC[3] is associated with the PF3 pin.
//#define ENABLE_ADC4        //ADC[4] is associated with the PF4 pin.
//#define ENABLE_ADC5        //ADC[5] is associated with the PF5 pin.
//#define ENABLE_ADC6        //ADC[6] is associated with the PF6 pin.
//#define ENABLE_ADC7        //ADC[7] is associated with the PF7 pin.
```

Note: ADC[0] is used for payload power monitoring

5.5 FRU information

The FRU information is divided in 5 zones: internal use area, chassis info area, board area, product info area and multi-record area. It is important to note that only the last three sections are used by the MMC software. All information required to generate the FRU information binary is defined in the user_code/fru_info.h file. The list below describes the fields of the different sections:

- Board area info: Contains the following information about the board
  - BOARD_MANUFACTURER: Manufacturer name (E.g.: “CERN”, max. 63 characters)
  - BOARD_NAME: Board name (E.g.: “AMC-Board” , max. 63 characters)
  - BOARD_SN: Board serial number (E.g.: “AMC-000001” , max. 63 characters)
  - BOARD_PM: Board Product number (E.g.: “00001” , max. 63 characters)
- Product information area: Contains the following information about the product
  - PRODUCT_MANUFACTURER: Product manufacturer name (max. 63 characters)
  - PRODUCT_NAME: Product name (E.g.: “MMC-Template” , max. 63 characters)
  - PRODUCT_PN: Product part number (E.g.: “0000” , max. 63 characters)
  - PRODUCT_VERSION: Product version (E.g.: “v1.0” , max. 63 characters)
  - PRODUCT_SN: Product serial number (E.g.: “sn:00000001” , max. 63 characters)
  - PRODUCT_ASSET_TAG: Product asset tag (E.g.: “”, max. 63 characters)
- MultiRecord area: Contains the following records
  - AMC point to point connectivity record (Optional)
  - AMC clock configuration record (Optional - foreseen)
  - Module current record (Mandatory)

The AMC point to point connectivity record is defined as shown below:

```
#define AMC_POINT_TO_POINT_RECORD_LIST                    \
        <p2p_definition>                                  \
        <p2p_definition>                                  \
        …

#define AMC_POINT_TO_POINT_RECORD_CNT          <number_of_p2p_definition>
```

Note: Only one <p2p_definition> must be set by port (only one ID by port).

Where <*p2p_definition*> should be one of the two macros described below:

- GENERIC_POINT_TO_POINT_RECORD(id, amc_port, protocol, ext, matching)
    - Id : Should be from 0 to *AMC_POINT_TO_POINT_RECORD_CNT* and unique
    - Port: PORT(n) where n is the AMC port number (from 0 to 11)
    - Protocol and ext:
        - For protocol PCIE, extension could be:
            - GEN1_NO_SSC
            - GEN1_SSC
            - GEN2_NO_SSC
            - GEN2_SSC
        - For protocol PCIE_ADV_SWITCHING, there is no extension (NO_EXT)
        - For protocol ETHERNET, extension could be:
            - BASE_1G_BX
            - BASE_10G_BX4
        - For protocol SERIAL_RAPID_IO, extension could be:
            - MBAUD_1250 (1.25 GBauds)
            - MBAUD_2500 (2.5 GBauds)
            - MBAUD_3125 (3.125 GBauds)
            - MBAUD_5000 (5.00 GBauds)
            - MBAUD_6250 (6.25 GBauds)
        - For protocol STORAGE, there is no extension (NO_EXT)
    - Matching:
        - EXACT_MATCHES
        - MATCHES_01
        - MATCHES_10

- OEM_POINT_TO_POINT_RECORD(id, port, oem_id, matching)
    - Id: Should be from 0 to *AMC_POINT_TO_POINT_RECORD_CNT* and unique
    - Port: PORT(n) where n is the AMC port number (from 0 to 11)
    - Oem_id: identifies the custom protocol (See OEM_GUID description below)
    - Matching:
        - EXACT_MATCHES
        - MATCHES_01
        - MATCHES_10

To identify an OEM connectivity, the carrier manager uses one GUID (Global Unique ID) number based on 16 bytes. The GUID format is defined in the Attachment A of the Wired for Management Baseline, Version 2.0 specification [5]. A GUID generator can be found on the web (E.g.: http://createguid.com/). The step given below shows how to register a GUID for an OEM protocol:

```
#define POINT_TO_POINT_OEM_GUID_CNT     <number_of_guid>
```

```
#define POINT_TO_POINT_OEM_GUID_LIST          \
        <oem_guid (oem_id = 0)>               \
        <oem_guid (oem_id = 1)>               \
        <oem_guid (oem_id = …)>
```

Where <oem_guid> shall be:

- OEM_GUID(guid_0_msb, g1, g2, g3, g4, g5, g6, g7, g8, g9, g10, g11, g12, g13, g14, guid_15_lsb)
    - guid_15_lsb to guid_0_msb are the 16 GUID bytes.

Below is an example of an AMC point to point connectivity declaration (user_code/fru_info.h):

```
#define POINT_TO_POINT_OEM_GUID_CNT                              2
#define POINT_TO_POINT_OEM_GUID_LIST                                                                \
 OEM_GUID(0x97,0x47,0x06,0xa2,0x2a,0x98,0x48,0xa9,0xbd,0x96,0x7b,0xf3,0x48,0x91,0x36,0x0f)         \
 OEM_GUID(0x46,0xbd,0xe8,0x5f,0x44,0xbd,0x44,0x56,0xa8,0x78,0x9f,0x4a,0x7b,0x03,0xfa,0x71)

#define AMC_POINT_TO_POINT_RECORD_CNT                5
#define AMC_POINT_TO_POINT_RECORD_LIST                                               \
 GENERIC_POINT_TO_POINT_RECORD(0, PORT(0), ETHERNET, BASE_1G_BX, EXACT_MATCHES)   \
 OEM_POINT_TO_POINT_RECORD(1, PORT(4), 0, EXACT_MATCHES)                          \
 GENERIC_POINT_TO_POINT_RECORD(2, PORT(5), PCIE, GEN1_NO_SSC, MATCHES_10)         \
 OEM_POINT_TO_POINT_RECORD(1, PORT(6), 1, EXACT_MATCHES)                          \
 GENERIC_POINT_TO_POINT_RECORD(4, PORT(7), PCIE, GEN1_NO_SSC, MATCHES_10)
```

5.6 SDR repository

The SDR (Sensor Data Record) information describes the sensors monitored by the MMC. Different record types exist and are described in the IPMI v1.5 standard. This document introduces only the two most frequently used types: Full sensors (E.g.: Temperature, voltage, current …) and Compact sensors (E.g.: flags …).

The sensors descriptions are present in user_code/sensors.h. Each SDR is a byte array described as follows (a commented example for a temperature sensor is available in the header file):

```
#define AMC<id>_RECORD  {     \
    SDR_byte[0],              \
    SDR_byte[1],              \
    …,                        \
    SDR_byte[n],              \
}
```

Note: Each line, except the last one, have to finish with a backslash character.

Note: Comments must be surrounded with /* and */ only.

The <id> parameter is an identifier used for record generation and must be an integer from 0 to 17. The MMC core is limited to 18 user sensors for this release but it could be extended (contact the MMC technical person at CERN to increase this limit).

Note: The device locator, hotswap and 12V generic SDR are implemented in the core. They must be not defined in the user code. The device locator record must be customized via the FRU_NAME macro present in the config.h file.

The table below (Table 4) describes Full Sensor records type (01h):

Byte	Name	Size	Description
1:2	Record ID	2	Filled by a MMC core function, set to 0000h
3	SDR Version	1	SDR Version, set to 51h for this version
4	Record type	1	Full sensor, set to 01h
5	Record length	1	Filled by a MMC core function, set to 00h
6	Sensor owner ID	1	Filled by a MMC core function, set to 00h
7	Sensor owner LUN	1	Filled by a MMC core function, set to 00h
8	Sensor number	1	Unique sensor number, set by user
9	Entity ID	1	Entity ID, set to C1h for AMC
10	Entity Instance	1	Filled by a MMC core function, set to 00h
11	Sensor initialization	1	Bit 6: Init scanning (1b: Enable / 0b: Disable) Bit 5: Init Events (1b: Enable / 0b: Disable) Bit 4: Init Thresholds (1b: Enable / 0b: Disable) Bit 3: Init hysteresis (1b: Enable / 0b: Disable) Bit 2: Init sensor type (1b: Enable / 0b: Disable) Bit 1: Set to 00h Bit 0: Set to 00h
12	Sensor capabilities	1	Set to F6h to be compliant with MMC core
13	Sensor type	1	Sensor types are listed in table 36-3, Sensor Type Code of the IPMI v1.5 standard. E.g.: Temp. (01h), Voltage (02h), Current (03h) ….
14	Event type code	1	Event type code are listed in table 36-1, Event/Reading Type Code Range of the IPMI v1.5 standard. E.g.: Threshold events (01h)
15:16	Assertion Event Mask	2	Described in Table 37-1, Full Sensor Record of the IPMI v1.5 standard. E.g.: 7Fh to enable all assertion events
17:18	Deassertion Event Mask	2	Described in Table 37-1, Full Sensor Record of the IPMI v1.5 standard. E.g.: 7Fh to enable all deassertion events
19:20	Discrete reading Mask	2	00FFh to be compliant with the MMC
21	Sensor units 1	1	Bits [7:6]: Analog (numeric) data format 00b: unsigned 01b: 1's complement (signed) 10b: 2's complement (signed) 11b: Does not return analog reading Bits [5:3]: Rate unit 000b: none 001b: per uS 010b: per ms 011b: per s 100b: per minute 101b: per hour 110b: per day 111b: reserved Bits [2:1]: Modifier unit 00b: none 01b: Basic unit / Modifier Unit 10b: Basic unit * modifier unit 11b: reserved Bit 0: Percentage

			0b: no 1b: yes
22	Base unit	1	Described in Table 37-14, Sensor Unit Type Codes of the IPMI v1.5 standard. E.g.: Degrees C (01h), Amps (05h), Volt (05h) …
23	Modifier unit	1	Idem, 00h if not specified
24	Linearization	1	enum (linear, ln, log10, log2, e, exp10, exp2, 1/x, sqr(x), cube(x), sqrt(x), cube-1 (x)) 00h: linear 70h: non-linear. 71h-7Fh: non-linear, OEM defined
25	M	1	M, LS 8 bits ($Sens_{val}$ = (M x Raw + B x 10^{Bexp}) + 10^{Rexp})
26	M, Tolerance	1	Bits[7:6]: M, MS 2 bits Bits[5:0]: Tolerance, unsigned in +/- ½ raw
27	B	1	B, LS 8 bit ($Sens_{val}$ = (M x Raw + B x 10^{Bexp}) + 10^{Rexp})
28	B, Accuracy	1	Bits[7:6]: B, MS 2 bits Bits[5:0]: Accuracy, LS 6 bits in raw
29	Accuracy, Accuracy exp	1	Bits[7:4]: Accuracy, MS 4 bits in raw Bits[3:2]: Accuracy exp, 2 bits unsigned Bits[1:0]: Reserved, set to 00b
30	R exp, B exp	1	Bits[7:4]: R exponent, 4 bits 2's complement signed Bits[3:0]: B exponent, 4 bits 2's complement signed
31	Analog characteristic flags	1	Set to 07h to be compliant with the MMC core
32	Nominal reading	1	Nominal sensor value in raw
33	Normal maximum	1	Normal maximum value in raw
34	Normal minimum	1	Normal minimum value in raw
35	Sensor maximum reading	1	Max reading val (E.g.: FFh for unsigned, 7Fh for signed)
36	Sensor minimum reading	1	Min reading val (E.g.: 00h for unsigned, 80h for signed)
37	Upper Non-rec. threshold	1	Upper non-recoverable threshold value in raw
38	Upper critical threshold	1	Upper critical threshold value in raw
39	Upper non-crit. threshold	1	Upper non-critical threshold value in raw
40	Lower non-rec. threshold	1	Lower non-recoverable threshold value in raw
41	Lower critical threshold	1	Lower critical threshold value in raw
42	Lower non-crit. threshold	1	Lower non critical threshold value in raw
43	Positive going hysteresis	1	Positive going threshold hysteresis value in raw (00h: no hysteresis)
44	Negative going-hysteresis	1	Negative going threshold hysteresis value in raw (00h: no hysteresis)
45	Reserved	1	Set to 00h
46	Reserved	1	Set to 00h
47	OEM	1	Set to 00h
48	ID String type/length	1	Bits[7:6]: Type (E.g.: 11b for ASCII) Bits[5:0]: ID string length in bytes
49:+N	ID String bytes	N	Sensor ID string bytes

Table 4: Full sensor SDR data

The table below (Table 5) describes Compact Sensor records type (02h):

Byte	Name	Size	Description
1:2	Record ID	2	Filled by a MMC core function, set to 0000h
3	SDR Version	1	SDR Version, set to 51h for this version
4	Record type	1	Full sensor, set to 01h
5	Record length	1	Filled by a MMC core function, set to 00h
6	Sensor owner ID	1	Filled by a MMC core function, set to 00h
7	Sensor owner LUN	1	Filled by a MMC core function, set to 00h
8	Sensor number	1	Unique sensor number, set by user
9	Entity ID	1	Entity ID, set to C1h for AMC
10	Entity Instance	1	Filled by a MMC core function, set to 00h
11	Sensor initialization	1	Bit 6: Init scanning (1b: Enable / 0b: Disable) Bit 5: Init Events (1b: Enable / 0b: Disable) Bit 4: Reserved, set to 00h Bit 3: Init hysteresis (1b: Enable / 0b: Disable) Bit 2: Init sensor type (1b: Enable / 0b: Disable) Bit 1: Set to 00h Bit 0: Set to 00h
12	Sensor capabilities	1	Set to F6h to be compliant with MMC core
13	Sensor type	1	Sensor types are listed in table 36-3, Sensor Type Code of the IPMI v1.5 standard. E.g.: Temp. (01h), Voltage (02h), Current (03h) ….
14	Event type code	1	Event type code are listed in table 36-1, Event/Reading Type Code Range of the IPMI v1.5 standard. E.g.: Threshold events (01h)
15:16	Assertion Event Mask	2	Described in Table 37-1, Full Sensor Record of the IPMI v1.5 standard. E.g.: 7Fh to enable all assertion events
17:18	Deassertion Event Mask	2	Described in Table 37-1, Full Sensor Record of the IPMI v1.5 standard. E.g.: 7Fh to enable all deassertion events
19:20	Discrete reading Mask	2	00FFh to be compliant with the MMC
21	Sensor units 1	1	Bits [7:6]: Analog (numeric) data format 00b: unsigned 01b: 1’s complement (signed) 10b: 2’s complement (signed) 11b: Does not return analog reading Bits [5:3]: Rate unit 000b: none 001b: per uS 010b: per ms 011b: per s 100b: per minute 101b: per hour 110b: per day 111b: reserved Bits [2:1]: Modifier unit 00b: none 01b: Basic unit / Modifier Unit 10b: Basic unit * modifier unit 11b: reserved Bit 0: Percentage

			0b: no 1b: yes
22	Base unit	1	Described in Table 37-14, Sensor Unit Type Codes of the IPMI v1.5 standard. E.g.: Degrees C (01h), Amps (05h), Volt (05h) …
23	Modifier unit	1	Idem, 00h if not specified
24:25	Sensor Record Sharing	2	Bits[15:14]: Reserved, set to 00h Bits[13:12]: ID String instance modifier type 00b: numeric 01b: alpha Bits[11:8]: Share count (number of sensor sharing this record). E.g.: if the starting sensor number was 10, and the share count was 3, then sensors 10, 11 and 12 would share this record. Bit[7]: Entity instance sharing. Set to 1b Bits[6:0]: ID String Instance modifier offset Multiple Discrete sensors can share the same sensor data record. The ID tring Instance Modifier and Modifier Offset are used to modify the Sensor ID tring as follows: Suppose sensor ID is "Temp " for 'Temperature Sensor', share count = 3, ID string instance modifier = numeric, instance modifier offset = 5 - then the sensors could be identified as: Temp 5, Temp 6, Temp 7. If the modifier = alpha, offset=0 corresponds to 'A', offset=25 corresponds to 'Z', and offset = 26 corresponds to 'AA', thus, for offset=26 the sensors could be identified as: Temp AA, Temp AB, Temp AC (alpha characters are considered to be base 26 for ASCII)
26	Positive going hysteresis	1	Positive going threshold hysteresis value in raw (00h: no hysteresis). Note: Cannot use shared record if sensors require individual hysteresis settings.
27	Negative going-hysteresis	1	Negative going threshold hysteresis value in raw (00h: no hysteresis). Note: Cannot use shared record if sensors require individual hysteresis settings.
45	Reserved	1	Set to 00h
46	Reserved	1	Set to 00h
47	OEM	1	Set to 00h
48	ID String type/length	1	Bits[7:6]: Type (E.g.: 11b for ASCII) Bits[5:0]: ID string length in bytes
49:+N	ID String bytes	N	Sensor ID string bytes

Table 5: Compact sensor SDR data

5.7 Power management

The power management (DC/DC control, Regulators enabling, etc) of an AMC must be taken care of by the MMC. The standard defines a few sequences to be executed: power ON sequence (Mandatory), power OFF sequence (Mandatory), reboot (Optional), warm reset (Optional) or cold reset (Optional). These sequences are user defined (depend on the AMC requirements).

The sequences configuration is described below (user_code/config.h):

```
#define POWER_ON_SEQ                \
        <action>                    \
        …

#define POWER_OFF_SEQ               \
        <action>                    \
        …

#define REBOOT_SEQ                  \
        <action>                    \
        …

#define WARM_RESET_SEQ              \
        <action>                    \
        …

#define COLD_RESET_SET              \
        <action>                    \
        …
```

Note: To disable optional sequences, the related define must be removed or commented out.

Note: Each line, except the last one, have to finish with a backslash character.

Note: Comments must be surrounded with /* and */ only.

The *<action>* parameter must be one of the macros described below:

- SET_PAYLOAD_SIGNAL(<signal>)
  - <signal>: name of the pin's signal (Appendix A)
- CLEAR_PAYLOAD_SIGNAL(<signal>)
  - <signal>: name of the pin's signal (Appendix A)
- WAIT_FOR_HIGH(<signal>,<timeout >,<error>)
  - <signal>: name of the pin's signal (Appendix A)
  - <timeout>: timeout in ms
  - <error>: could be C code (executed in if statement) or one of the following macros
    - PON_ERROR: Send a power ON failure event to the MCH and then, execute POWER_OFF_SEQ.
    - PON_CONTINUE: Continue the in progress sequence
    - POFF_ERROR: Stop the sequence

- WAIT_FOR_LOW(<signal>,<timeout >,<error>)
    - <signal>: name of the pin's signal (Appendix A)
    - <timeout>: timeout in ms
    - <error>: could be C code (executed in if statement) or one of the following macros
        - PON_ERROR: Send a power ON failure event to the MCH and then, execute POWER_OFF_SEQ.
        - PON_CONTINUE: Continue the in progress sequence
        - POFF_ERROR: Stop the sequence
- SET_REGISTER(<reg_name>,<value>)
    - <reg_name>: register name (e.g.: DDRx, PORTx …)
        - <value>: value to set in the register
- DELAY(<delay >)
    - <delay>: delay in ms
- CUSTOM_C(<c_code>)
    - <c_code>: user's C code to perform custom action (configure I²C component …)

Below is an example of the power ON sequence:

```
#define POWER_ON_SEQ                                                                       \
   SET_PAYLOAD_SIGNAL(LOCAL_DCDC_ENABLE)         /* Set LOCAL_DCDC_ENABLE signal to high */     \
    SET_PAYLOAD_SIGNAL(LOCAL_REG_ENABLE)         /* Set LOCAL_REG_ENABLE signal to high */      \
    WAIT_FOR_LOW(LOCAL_FPGA1_INIT_DONE, 500, PON_ERROR)      /* Wait for LOCAL_FPGA1_INIT_DONE */  \
    SET_REGISTER(DDRA, (DDRA & 0x0F) | 0x04)                 /* Set DDRA register */          \
    CUSTOM_C(                                                /* Execute custom c code */      \
        /* Put your C code here (below is an example) */                                      \
        int myvar = 0;                                                                        \
        for(myvar =0; myvar < 5; myvar ++)                                                    \
            PORTA = get_ipmi_address()+myvar;                                                 \
    )                                                                                         \
    DELAY(500)                         /* Delay of 500 ms */                                  \
    CLEAR_PAYLOAD_SIGNAL(GPIO_1)       /* Set GPIO_1 signal to low */
```

5.8 E-keying

The e-keying specification, included in the AMC.0 standard [2], describes an automatic feature to check port compatibility between modules installed on a common backplane. The AMC ports must be defined in the FRU information (section 5.5). This information, complemented with the backplane information, is used to check the compatibility during the AMC initialization phase. Upon AMC board insertion and when the payload power is enabled, the carrier manager sends the "set AMC Port State (Enable)" command to enable all compatible AMC ports. Similarly, during the extraction procedure, the AMC ports are disabled with the "set AMC port State (Disable)" command that is sent before the payload power is disabled. The three user functions defined below (user_code/ekeying.c) are used to perform initialization, enabling and disabling actions:

- void ekeying_init()
    - By default, all AMC ports are defined as disabled. Users can modify it by calling the following function: set_channel_init(<desc_id>, <state>).
        - <desc_id>: defines the port specified. The port is selected by the associated ID defined in the point to point record of the FRU information (section 5.5).
        - <state>: Define the initialization state and can be:
            - PORT_ACTIVE
            - PORT_INACTIVE

- u08 port_ekeying_enable(u08 id)
  - This function is called when the "set AMC port state (Enable)" command is received from the carrier manager. In this function, the user can configure devices (E.g.: enable interface, configure switch …) with C functions. The macros defined in section 5.10 can also be used.
  - Id: defines the specified port. The port is selected by the associated ID defined in the point to point record of the FRU information (section 5.5).
  - Returned value:
    - SUCCES
    - FAILED
    - NI (Not Implemented, inform that this port cannot be controlled)

- u08 port_ekeying_enable(u08 id)
  - This function is called when the "set AMC port state (disabled)" command is received from the carrier manager. In this function, the user can configure devices (E.g.: disable interface, remove switch configuration …) with C functions. The macros defined in section 5.10 can also be used.
  - Id: defines the specified port. The port is selected by the associated ID defined in the point to point record of the FRU information (section 5.5).
  - Returned value:
    - SUCCES
    - FAILED
    - NI (Not Implemented, inform that this port cannot be controlled)

5.9 Sensors

Two functions are dedicated to the user's sensors. One for initialization and one for monitoring. These functions are implemented in the user_code/sensors.c file with the following prototypes: *void sensor_init_user()* and void *sensor_monitoring_user()*.

How to send/get information to/from an I^{2}C based sensor:

- GET_I2C_VAL(<address>,<sub_addr>,<sub_addr_type>,<len>,<buf>)
  - <address>: I2C address of the device
  - <sub_addr>: Sub-address / register address
  - <sub_addr_type>: length of the sub-address
    - ZERO_LEN: no sub-address
    - BYTE_LEN: 1 sub-address byte
    - SHORT_LEN: 2 sub-address byte
  - <len>: number of byte to be read
  - <buf>: pointer to unsigned char (u08) array where the read byte should be stocked

- SEND_I2C_VAL(<address>,<sub_addr>,<sub_addr_type>,<len>,<buf>)
    - <address>: I2C address of the device
    - <sub_addr>: Sub-address / register address
    - <sub_addr_type>: length of the sub-address
        - ZERO_LEN: no sub-address
        - BYTE_LEN: 1 sub-address byte
        - SHORT_LEN: 2 sub-address byte
    - <len>: number of byte to be sent
    - <buf>: pointer to unsigned char (u08) array containing bytes to be sent

How to read an analogue value from a microcontroller ADC pin:

- GET_ADC(<chID>)
    - <chID>: ADC channel ID to be read
    - Returned value: unsigned char (u08) – value read by the ADC

How to set/clear a MMC microcontroller GPIO pin:

- SET_SIGNAL(<signal>)
    - <signal>: name of the pin's signal (Appendix B)
- CLEAR_SIGNAL(<signal>)
    - <signal>: name of the pin's signal (Appendix B)

How to register the sensor value:

- set_sensor_value(<sensor_number>,<value>)
    - <sensor_number>: sensor number specified in the SDR
    - <value>: unsigned char (u08) value

5.10 Custom LEDs

The PICMG standard defines functions to control and monitor LEDs. Three LEDs are described in the specification: the blue led (mandatory), green led (optional – implemented) and red led (optional – implemented). Moreover, custom LEDs can be defined and controlled with the same functions or by the MMC application itself. The LEDs are implemented as described below:

```
#define AMC_USER_LED_LIST          {        \
    <led array (ledID = 3)>,                \
    <led array (ledID = 4)>,                \
    …                                       \
    <led array (ledID = n)>                 \
}
```

Note: the ledID is automatically incremented and starts from 3.

Note: Each line, except the last one, have to finish with a backslash character and comments must be surrounded with /* and */ only.

Where <led array> can be one of the two arrays described below (depending on the way the LED is controlled):

- LED controlled through IO Extender (PCF8574 family):

```
{                                                   \
    io_type: IO_EXTENDER_PCF8574AT,                 \
    addr: <i2c_address>                     \
    pin: <pin number>                               \
    colour: <colour>                                \
    init: <init_state>                              \
    active: <pin_state>                             \
    inactive: <pin_state>                   \
},
```

  - <i2c_address>: I²C address of the IO extender
  - <pin number>: Pin of the IO extender (from 1 to 8)
  - <colour>: LED colour, can be one of the following value
    - BLUE
    - RED
    - GREEN
    - AMBER
    - ORANGE
    - WHITE
  - <init_state>: Initialization state of the LED, can be one of the following value
    - ACTIVE (led ON)
    - INACTIVE (led OFF)
  - <pin_state>: pin value for active/inactive state, can be one of the following value
    - LOW
    - HIGH

- LED controlled by a MMC microcontroller pin:

```
{                                                   \
    io_type: MMC_PORT,                              \
    port: <port>                                    \
    pin: <pin>                                      \
    colour: <colour>                                \
    init: <init_state>                              \
    active: <pin_state>                             \
    inactive: <pin_state>                           \
},
```

  - <port>: pin’s port must be set as follow: PORT(<signal>)
    - <signal>: name of the pin’s signal (Appendix B)
  - <pin>: MMC pin, set as follow: PIN(<signal>)
    - <signal>: name of the pin’s signal (Appendix B)

5.11 OEM commands

The OEM commands defined by the IPMI v1.5 standard [1] are user defined IPMI commands. These can be executed with the netFN 2Eh. To enable this feature, the ENABLE_OEM macro must be set in the user_code/config.h file and the ipmi_oem_user function must be implemented in the user_code/user_code.c file.

Enable oem command (user_code/config.h):

#define ENABLE_OEM

ipmi_oem_user function:

u08 ipmi_oem_user(u08 cmd , u08 *iana, u08 * data, u08 data_len, u08 *buf, u08 *error)

- <cmd>: command received
- <iana>: 3 bytes array containing the IANA identifier (must be checked)
- <data>: data received
- <data_len>: number of received data bytes
- <buf>: bytes array pointer to set data to be sent (3 first bytes must be the IANA)
- <error>: IPMI completion code value (see Appendix C)
- Returned value: Number of bytes to be sent (response)

Below is an example of the implementation of the following OEM command:

- Command: 01h
- IANA: 000060h
- Cmd data length: 1 byte
- Cmd data: data[0] = <eg0>
- Returned data: data[0] = <eg0>

```
u08 ipmi_oem_user(u08 cmd, u08 *iana, u08 * data, u08 data_len, u08 *buf, u08 *err){

    //Note: You must not return more than "MAX_BYTES_READ" bytes
    u08 res_data_len = 0;

    *err = IPMI_CC_OK;

    if (iana[0] != 0x00 || iana[1] != 0x00 || iana[2] != 0x60){
              *error = IPMI_CC_PARAM_OUT_OF_RANGE;
              return 0;              //Wrond IANA code
    }

    buf[0] = buf[1] = 0x00;   //IANA ID must be returned as the first 3 bytes
    buf[2] = 0x60;

    switch(command){
       case 0x01:    if(data_size == 1){
                         buf[3] = user_data[0];
                         res_data_len = 4;
                     }else{
                         *err = IPMI_CC_PARAM_OUT_OF_RANGE;
                         return 0;
                     }
                     break;
```

```
        default:      *err = IPMI_CC_PARAM_OUT_OF_RANGE;
                      return 0;

    }

    return res_data_len;
}
```

5.12 Controller specific commands

The controller specific commands are defined in the IPMI v1.5 standard [1]. These can be executed with the netFN 30h. To enable this feature, the ENABLE_CONTROLLER_SPECIFIC macro must be set in the user_code/config.h file and the ipmi_controller_spec function must be implemented in the user_code/user_code.c file.

Enable controller specific command (user_code/config.h):

#define ENABLE_CONTROLLER_SPECIFIC

ipmi_oem_spec function:

u08 ipmi_controller_spec(u08 cmd , u08 * data, u08 data_len, u08 *buf, u08 *err)

- <cmd>: command received
- <data>: data received
- <data_len>: number of received data bytes
- <buf>: bytes array pointer to set data to be sent (3 first bytes must be the IANA)
- <err>: IPMI completion code value (see Appendix C)
- Returned value: Number of bytes to be sent (response)

Below is an example of the implementation of the following controller specific command:

- Command: 01h
- Cmd data length: 1 byte
- Cmd data: data[0] = <eg0>
- Returned data: data[0] = <eg0>

```
u08 ipmi_controller_specific(u08 cmd, u08 *data, u08 data_len, u08 *buf, u08 *err){

    u08 rsp_length = 0;

    *error = IPMI_CC_OK;

    switch(command){
       case 0x01:
            buf[0] = data[0];
            rsp_length = 1;
            break;
       default:
            *error = IPMI_CC_INV_CMD;
    }
    return rsp_length;
}
```

5.13 Bench top

A custom geographical addresses can be defined to power the AMC card in bench top use (outside of an xTCA shelf). These addresses must be outside of the PICMG specification range and can be defined in the user_code/config.h file as follow:

```
#define CUSTOM_ADDR_LIST                                              \
    ADDR(<addr>,<gaddr_0>,<gaddr_1>,<gaddr_2>)                        \
    …
```

Where:

- <addr>: custom address, should be out of PICMG specification (E.g.: FFh)
- <gaddr_0>: value for GA0 pin associated to this address
    - POWERED: Bit is set
    - GROUNDED: bit is cleared
    - UNCONNECTED: bit is unconnected
- <gaddr_1>: value for GA1 pin associated to this address (same as above)
- <gaddr_2>: value for GA2 pin associated to this address (same as above)

If custom addresses are used, the user_main function should be implemented in the user_code/user_code.c file as follow:

- u08 user_main(u08 addr){ /* user code */ }
    - addr: address detected
    - Returned value:
        - 0: To continue the MMC core program when exit
        - Others: To stop the MMC core program when exit

This function is executed if one of the user's defined address is detected during the MMC initialization. Below is an example of a user_main function that execute POWER_ON_SEQ when the handle switch is asserted and POWER_OFF_SEQ when it is de-asserted:

```
u08 user_main(u08 addr){
        while(1)
                manage_payload();

        return 1;
}
```

Moreover, sensors can be monitored with the function sensor_monitoring_user() defined in user_code/sensors.c. The sensor values can be read with:

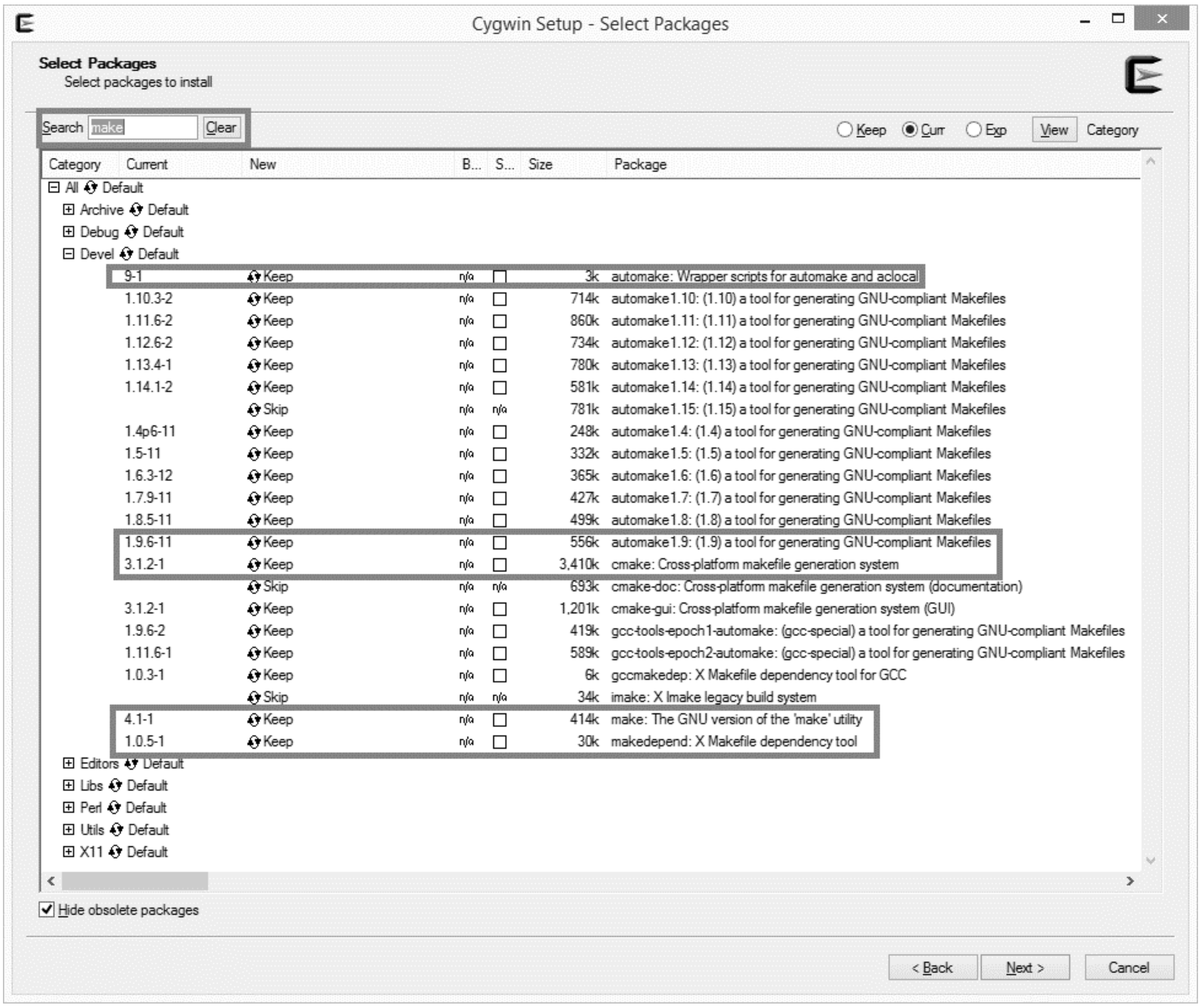
- get_sensor_value(u08 sensID)
    - sensID: sensor number defined in SDR
    - Returned value: raw sensor value

6 Appendix A: Cygwin installation on Windows

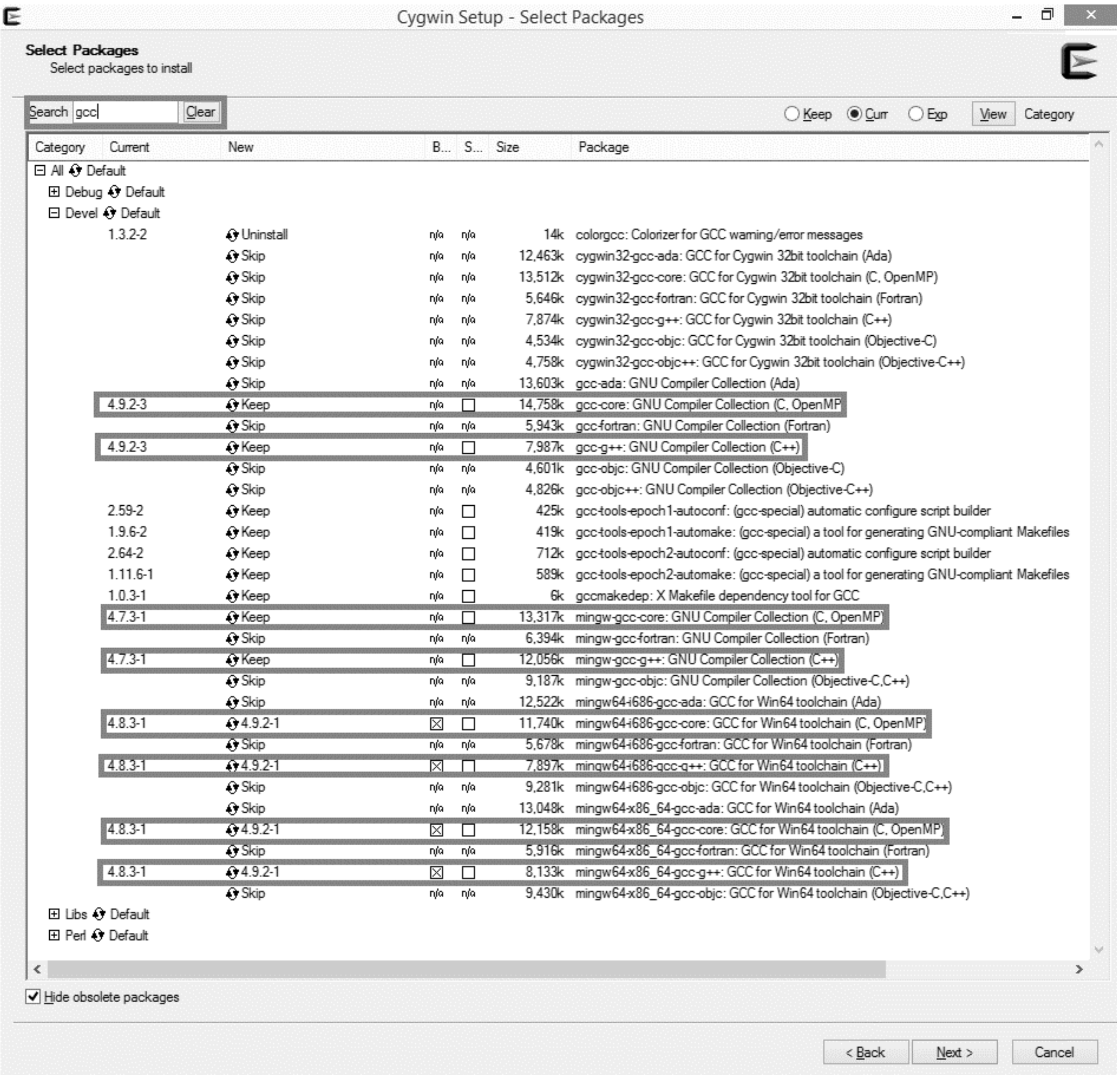
Cygwin is a Unix-like command line interface for Windows. It can be downloaded from the project website (https://cygwin.com/install.html). During the installation process, the following packet must be selected to use the MMC related tools:

- Make
- GCC
- LibSSL

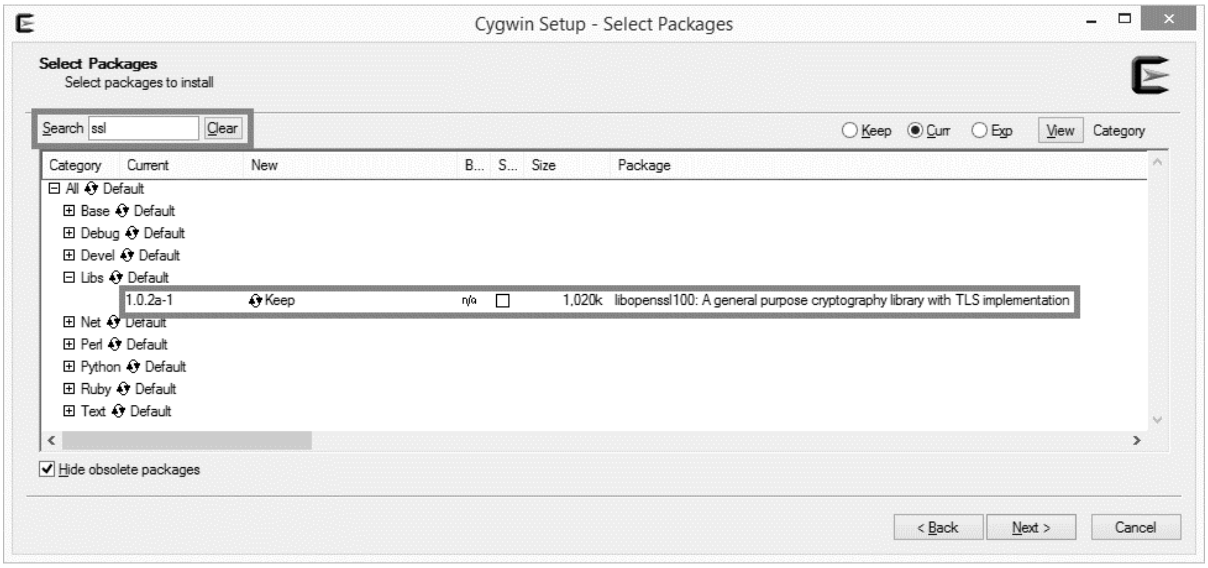
Make:



Gcc:


Cygwin Setup - Select Packages
Select Packages
Select packages to install
Search gcc Clear
Keep Curr Exp View Category
Category Current New B... S... Size Package
All Default
Debug Default
Devel Default
1.3.2-2 Uninstall n/a n/a 14k colorgcc: Colorizer for GCC warning/error messages
Skip n/a n/a 12,463k cygwin32-gcc-ada: GCC for Cygwin 32bit toolchain (Ada)
Skip n/a n/a 13,512k cygwin32-gcc-core: GCC for Cygwin 32bit toolchain (C, OpenMP)
Skip n/a n/a 5,646k cygwin32-gcc-fortran: GCC for Cygwin 32bit toolchain (Fortran)
Skip n/a n/a 7,874k cygwin32-gcc-g++: GCC for Cygwin 32bit toolchain (C++)
Skip n/a n/a 4,534k cygwin32-gcc-objc: GCC for Cygwin 32bit toolchain (Objective-C)
Skip n/a n/a 4,758k cygwin32-gcc-objc++: GCC for Cygwin 32bit toolchain (Objective-C++)
Skip n/a n/a 13,603k gcc-ada: GNU Compiler Collection (Ada)
4.9.2-3 Keep n/a 14,758k gcc-core: GNU Compiler Collection (C, OpenMP)
Skip n/a n/a 5,943k gcc-fortran: GNU Compiler Collection (Fortran)
4.9.2-3 Keep n/a 7,987k gcc-g++: GNU Compiler Collection (C++)
Skip n/a n/a 4,601k gcc-objc: GNU Compiler Collection (Objective-C)
Skip n/a n/a 4,826k gcc-objc++: GNU Compiler Collection (Objective-C++)
2.59-2 Keep n/a 425k gcc-tools-epoch1-autoconf: (gcc-special) automatic configure script builder
1.9.6-2 Keep n/a 419k gcc-tools-epoch1-automake: (gcc-special) a tool for generating GNU-compliant Makefiles
2.64-2 Keep n/a 712k gcc-tools-epoch2-autoconf: (gcc-special) automatic configure script builder
1.11.6-1 Keep n/a 589k gcc-tools-epoch2-automake: (gcc-special) a tool for generating GNU-compliant Makefiles
1.0.3-1 Keep n/a 6k gccmakedep: X Makefile dependency tool for GCC
4.7.3-1 Keep n/a 13,317k mingw-gcc-core: GNU Compiler Collection (C, OpenMP)
Skip n/a n/a 6,394k mingw-gcc-fortran: GNU Compiler Collection (Fortran)
4.7.3-1 Keep n/a 12,056k mingw-gcc-g++: GNU Compiler Collection (C++)
Skip n/a n/a 9,187k mingw-gcc-objc: GNU Compiler Collection (Objective-C,C++)
Skip n/a n/a 12,522k mingw64-i686-gcc-ada: GCC for Win64 toolchain (Ada)
4.8.3-1 4.9.2-1 11,740k mingw64-i686-gcc-core: GCC for Win64 toolchain (C, OpenMP)
Skip n/a n/a 5,678k mingw64-i686-gcc-fortran: GCC for Win64 toolchain (Fortran)
4.8.3-1 4.9.2-1 7,897k mingw64-i686-gcc-g++: GCC for Win64 toolchain (C++)
Skip n/a n/a 9,281k mingw64-i686-gcc-objc: GCC for Win64 toolchain (Objective-C,C++)
Skip n/a n/a 13,048k mingw64-x86_64-gcc-ada: GCC for Win64 toolchain (Ada)
4.8.3-1 4.9.2-1 12,158k mingw64-x86_64-gcc-core: GCC for Win64 toolchain (C, OpenMP)
Skip n/a n/a 5,916k mingw64-x86_64-gcc-fortran: GCC for Win64 toolchain (Fortran)
4.8.3-1 4.9.2-1 8,133k mingw64-x86_64-gcc-g++: GCC for Win64 toolchain (C++)
Skip n/a n/a 9,430k mingw64-x86_64-gcc-objc: GCC for Win64 toolchain (Objective-C,C++)
Libs Default
Perl Default
Hide obsolete packages
< Back Next > Cancel

LibSSL:


Cygwin Setup - Select Packages
Select Packages
Select packages to install
Search ssl Clear
Keep Curr Exp View Category
Category Current New B... S... Size Package
All Default
Base Default
Debug Default
Devel Default
Libs Default
1.0.2a-1 Keep n/a 1,020k libopenssl100: A general purpose cryptography library with TLS implementation
Net Default
Perl Default
Python Default
Ruby Default
Text Default
Hide obsolete packages
< Back Next > Cancel

7 Appendix B: MMC microcontroller signals

Pin	Signal name
PA0	LOCAL_LOW_VOLTAGE_POK
PA2	RTM_PS or GPIO_13
PA3	RTM_12V_ENABLE or GPIO_14
PA4	RTM_3V3_ENABLE or GPIO_15
PA5	RTM_I2C_ENABLE or GPIO_16
PB0	GA_PULLUP
PB1	GA2
PB2	GA1
PB3	GA0
PB5	LOCAL_RED_LED
PB6	LOCAL_GREEN_LED
PB7	LOCAL_BLUE_LED
PC2	LOCAL_RESET_FPGA **or** GPIO_0
PC3	LOCAL_RELOAD_FPGA **or** GPIO_2
PC4	LOCAL_FPGA2_INIT_DONE **or** GPIO_1
PC5	LOCAL_FPGA1_INIT_DONE **or** GPIO_3
PC6	LOCAL_REG_ENABLE **or** GPIO_4
PC7	LOCAL_DCDC_ENABLE **or** GPIO_5
PD0	IPMB_SCL
PD1	IPMB_SDA
PD2	LOCAL_HANDLE_SWITCH
PD4	LOCAL_I2C_SCL
PD5	LOCAL_I2C_SDA
PE2	PS1
PE3	PS0
PE4	GPIO_10
PE5	GPIO_11
PE6	GPIO_9
PE7	GPIO_12
PF0	PRESENCE_12V
PF1	GPIO_6
PF2	GPIO_7
PF3	GPIO_8
PG0	MASTER_TCK
PG1	MASTER_TMS
PG2	MASTER_TDO
PG3	MASTER_TDI

8 References

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