Hermes™ IoT Development Platform Hardware Reference Manual

1 Platform Overview

Hermes is built around a BeagleBone Black (BBB) (www.beagleboard.org) single-board computer controlling a wireless sensor reader board for communicating with sensor tags. Figure 1 shows Hermes block diagram.

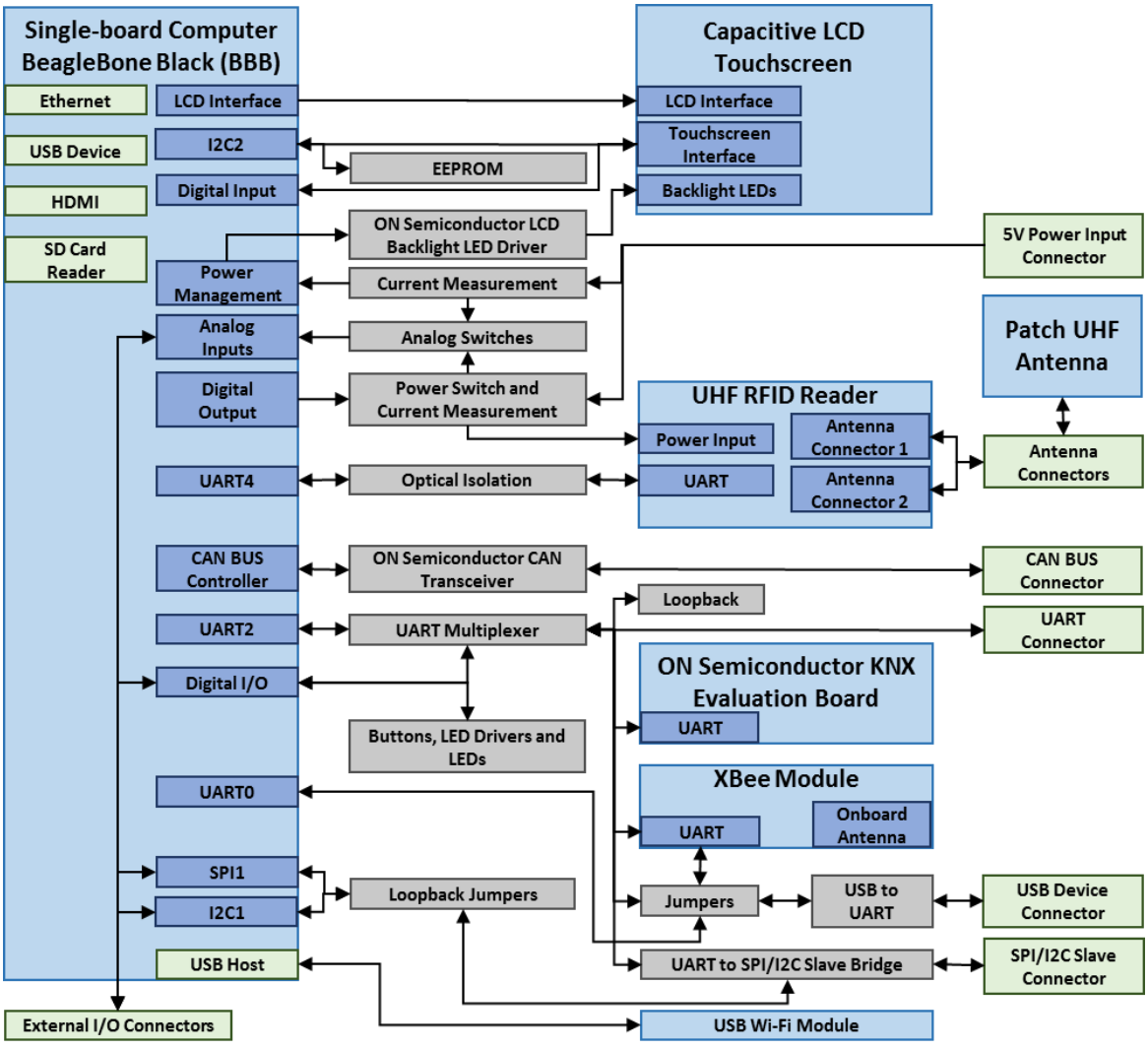

Figure 1 Hermes Block Diagram

Hermes's main components are:

1. BeagleBone Black single-board computer

2. Capacitive LCD touchscreen
3. UHF RFID reader
4. Patch UHF antenna
5. Power distribution
6. EEPROM
7. USB Wi-Fi module
8. CAN BUS interface
9. UART multiplexer
10. USB-UART interface
11. XBee module
12. KNX evaluation board
13. I2C/SPI slave interface
14. Buttons, LED drivers and LEDs

2 BeagleBone Black Single-Board Computer

Hermes uses as its main controller a BeagleBone Black Revision C.

The following references provide detailed information of every aspect of the BBB:

http://beagleboard.org/BLACK

http://elinux.org/Beagleboard:BeagleBoneBlack

There are also many other websites with extensive information about the BBB. Two of the most useful are:

http://derekmolloy.ie/beaglebone/

https://eewiki.net/display/linuxonarm/BeagleBone+Black

Dr. Derek Molloy not only owns one of the previous websites, but he also published the following very informative book: **Exploring BeagleBone: Tools and Techniques for Building with Embedded Linux** (ISBN-13: 978-1118935125). There is also an e-book version with up-to-date information.

Figure 2 shows the BeagleBone Black connectors that are of interest for the Hermes platform:

1. P8 and P9
2. J1
3. Ethernet
4. USB Host
5. USB Client
6. HDMI

7. SD Card

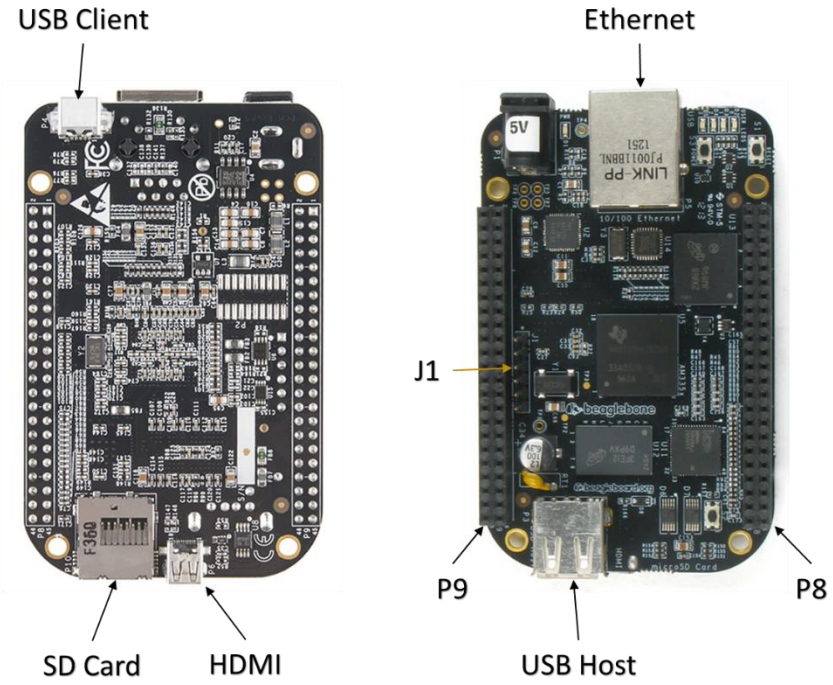

Figure 2 BeagleBone Black Connectors

2.1 P8 and P9 Connectors

The BBB exposes most of its hardware resources through the P8 and P9 connectors. Each one has 46 pins, and Hermes uses most of them.

2.1.1 Analog Inputs

The seven analog inputs at P9 have power off protection provided by analog switches (U14 and U15). The switches are powered and enabled with SYS_V5. Therefore, the switches will automatically be connected when the BBB is on, and the switches will break when the BBB goes off.

2.1.2 Current Measurement Circuit

P9 is also used to provide power to the BBB using the pins P9-5 and P9-6 (VDD_5V). The applied power goes through a current measurement circuit that uses a 0.01 Ohm resistor (R64) and an amplifier (U18) configured with a fixed gain of 25. The signal is fed to the BBB using the analog input AI3. Considering that the ADC has 12 bits and a reference voltage of 1.8V, then the current consumption can be calculated as:

$$BBB\ Current\ Consumption\ (mA) = \frac{1.8 * 1000 * \mathrm{ADC(code)}}{4096 * 25 * 0.01} = 1.758 * ADC(code)$$

The ADC code can be obtained by reading the file located at:

```
/sys/bus/iio/devices/iio:device0/in_voltage3_raw
```

2.2 J1 UART0 Debug Connector

Hermes provides the J1 connector that mates with the BBB's J1 connector, thus allowing the Hermes on-board USB-UART adapter to connect to UART0. See Section 10.2 for details on how to enable this capability through the use of jumpers.

UART0 in the BBB provides a terminal interface that it also shows all events thrown by the bootloader and the Linux operating system. This is very useful for debugging and troubleshooting from an external Windows- or Linux- based computer. The terminal emulator is also useful for software development purposes.

2.3 Ethernet Connector

This connector can be used to provide a wired connection to a network. DHCP is enabled by default.

2.4 USB 2.0 Type A Jack Host Connector

Hermes uses this port to provide Wi-Fi connectivity through the use of a USB/Wi-Fi adapter. But this connector can also be used to connect an external mouse or keyboard. It is possible to use a USB Hub when there is need to connect two or more devices. It is highly recommended to use an externally powered USB Hub when the Wi-Fi adapter is plugged into the hub.

2.5 USB 2.0 Mini Type B Jack Client Connector

An external computer can be connected to the BBB using this connector. Under Microsoft Windows and Linux, the BBB will show up with three different interfaces:

1. As a hard-drive
2. As a network adapter using RNDIS
3. As a serial COM port

The hard-drive contains documentation and device drivers. The network adapter is very useful for software development and troubleshooting: it allows the use of SSH and terminal emulation. Finally, the serial port can be used with terminal emulation software. See the BBB documentation for details.

2.6 HDMI Connector

It is possible to connect an external HDMI monitor or LCD panel. Please review the BBB documentation regarding compatibility issues. It is not possible to simultaneously use the

Hermes on-board touchscreen and HDMI. Also, it is not possible to use the BBB's SPI1 lines and HDMI at the same time. To use HDMI, follow the next steps:

1. Disable the default Hermes hardware resources cape and enable the Hermes with no SPI cape. This can be done by opening the file at **/etc/default/capemgr** with root privileges. Follow the instructions in the file.
2. Download the latest version of the file **HERMES-HW-NOSPI-00A0.dtbo** from GitHub. This can be done with the following command:
   a. `wget -O HERMES-HW-NOSPI-00A0.dts https://github.com/RFMicron/Hermes/blob/master/DebianCustomization/Capes/HERMES-HW-NOSPI-00A0.dts?raw=true`
3. Copy this file to the **/lib/firmware** folder and change the privileges with these commands:
   a. `sudo cp HERMES-HW-NOSPI-00A0.dtbo /lib/firmware`
   b. `sudo chmod 750 /lib/firmware/HERMES-HW-NOSPI-00A0.dtbo`
4. Unplug the BBB module from the Hermes main PCB.
5. Unplug the header adapter that is located between P8 in the BBB and J8.
6. Disconnect pin J8-28 (LCD-PCLK). This can be easily done in two ways:
   a. Pull the pin out of the header adapter. See Figure 3.

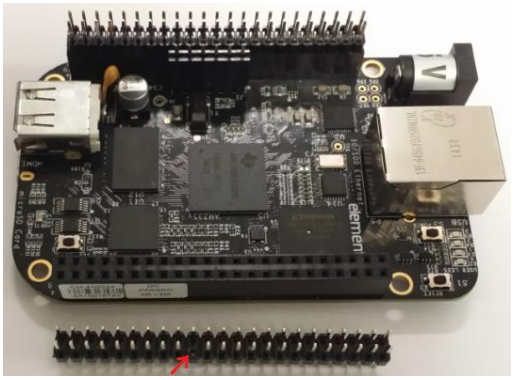

Figure 3 Header adapter without pin 28

   b. Place the header adapter with an offset of 10 pins out of J8 in order to avoid the connections of pins J8-27 through J8-46. These pins are intended for the on-board LCD touchscreen and are not needed when using HDMI. See Figure 4.

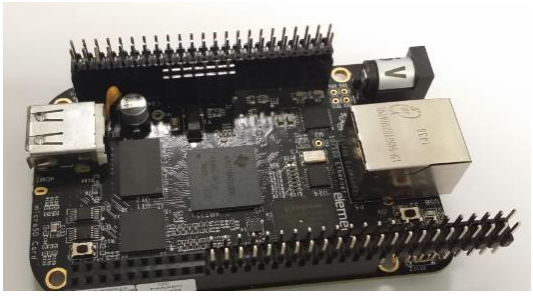

Figure 4 Header adapter placed with 10-pin offset

7. Plug the BBB back to the Hermes main board. Pay attention to the J1 connector to make sure it gets properly connected.
8. Put a jumper on J25. This will disable the Hermes cape loading during boot up thus allowing the default HDMI cape to load.
9. Plug in the power adapter. The BBB will automatically boot after that.

2.7 SD Card Reader

The SD Card has the following uses:

1. Provide additional storage space.
2. Boot an operating system from the SD Card and either use or not use the BBB's EEPROM. Not using the EEPROM frees ten digital lines that are available through Hermes J33 connector.
3. Flash the BBB's EEPROM. Hermes provides an SD Card that can be used to restore the EEPROM to its factory state. See the Hermes User's Manual for details.

2.8 Replacement Procedure

The BBB can be replaced with any other BBB Revision C. Plug the BBB to the Hermes main board. Pay attention to the J1 connector to make sure it gets properly connected. To achieve full Hermes functionality, the BBB has to be flashed with the Hermes SD Card. The Hermes SD Card provides the following features:

1. A customized version of the Linux kernel that enables the use of the capacitive LCD touchscreen and buttons.
2. BBB cape files that enable the Hermes onboard hardware resources.
3. Hermes software and platform drivers.
4. The jEdit application, Florence virtual keyboard and CAN BUS utilities.

3 Capacitive LCD Touchscreen

There are three main components in the integration of the capacitive LCD touchscreen with Hermes:

1. LCD display digital lines
2. Backlight LED driver
3. Touchscreen I2C interface

3.1 LCD Display Digital Lines

The LCD is integrated using the RGB565 configuration. Therefore, only 16 out of the 24 data lines of the LCD are used in J3 providing a 16-bit color depth.

3.2 Backlight LED Driver

The backlight LED driver is implemented using ON Semiconductor's CAT4139 high current boost LED driver. This driver has open LED overvoltage protection, so there is no need to add a protection Zener diode at the output. The SHDN signal is connected to a BBB's pulse width modulation (PWM) source. The PWM signal can be controlled from Linux providing one hundred different levels of LED dimming from completely dark to 100% on all the time, which is the default case.

3.3 Touchscreen I2C Interface

The touchscreen is connected to the BBB's I2C2 bus, and one digital input signal (LCD_INT) is used for interruptions. The RESET signal is pulled-up, but there is an option to be connected to a BBB's digital signal (GPIO2_5) if R69 is populated with a zero-Ohm resistor. The software driver can be configured to use the RESET signal through the device three configuration file.

4 UHF RFID Reader

The AMS Radon kit is integrated into Hermes. All documentation about the reader is provided at https://github.com/RFMicron/Hermes/tree/master/HardwareDocs/amsDocs/Demo%20Kit%20Radon. The documentation includes schematics, gerbers, bill of materials, manual, one application note and the installer for the AMS factory firmware. It's important to clarify that the reader integrated to the Hermes kit has a customized version of the firmware. The source code and firmware are available at https://github.com/RFMicron/Hermes.

WARNING: The AMS Radon reader with its original factory firmware will NOT WORK WITH HERMES.

There are four components in the integration of the reader with Hermes:

1. Power signals
2. UART signals
3. Microcontroller signals
4. Antenna signals

4.1 Power Signals

The power applied to the reader goes through a power switch (U20). A digital line from the BBB (GPIO0_7) controls the power switch. This way the software can turn on and off the reader as needed. After the power switch there is a current measurement circuit that uses a 0.01 Ohm resistor (R65) and an amplifier (U19) configured with a fixed gain of 25. The signal is fed to the BBB using the analog input AI2. Considering that the ADC has 12 bits and a reference voltage of 1.8V, then the current consumption can be calculated as:

$$Reader\ Current\ Consumption\ (mA) = \frac{1.8 * 1000 * \mathrm{ADC(code)}}{4096 * 25 * 0.01} = 1.758 * ADC(code)$$

The ADC code can be obtained by reading the file located at:

```
/sys/bus/iio/devices/iio:device0/in_voltage2_raw
```

4.2 UART Signals

The BBB uses UART4 to communicate with the reader. There is optical isolation in between provided by U17. The reason for the optical isolation is because the digital signals within the reader have a ground that is different from Hermes ground.

4.3 Microcontroller Signals

Hermes provides a connector (J40) that clones the signals from the reader's J6 connector. J40 is useful when there is need to load firmware into the reader's microcontroller.

4.4 Antenna Signals

The two antenna signals are routed through Hermes main PCB to facilitate their use with the SMA connectors and to increase the service life of the reader's SMB connectors.

5 Power Distribution

Hermes uses a 5V power supply with 5A capacity. Hermes has a replaceable 3.5A fuse. The input power goes to only two places: the BBB and the reader. The BBB receives unregulated power at the VDD_5V pins and it supplies regulated power to the rest of the Hermes board through VDD_3V3B and SYS_5V.

The USB-UART interface is self-powered from the USB bus.

The KNX evaluation board is self-powered by design from the KNX bus.

6 EEPROM

The EEPROM in the Hermes PCB (U12) is used to provide device tree cape capability. The BBB during boot time reads the EEPROM and finds the configuration information that allows it to select and load the RFMICRON_HERMES device tree file.

The contents of the EEPROM can be displayed using the following command:

```
sudo cat /sys/bus/i2c/devices/1-0054/eeprom | hexdump -C
```

Hermes has the EEPROM write protection enabled by default. Writing to the EEPROM can be enabled with a jumper between pins J28-13 and J28-14.

WARNING: If the RFMICRON_HERMES cape configuration is altered in the EEPROM then the operating system won't be able to find the right device tree and the LCD touchscreen will stop working. The only way to fix this problem is by restoring the right configuration to the EEPROM.

7 USB Wi-Fi Module

The Hermes USB Wi-Fi adapter is the D-Link DWA-121. This model is used because it has the chipset RTL8192CU. This chipset is supported by the Linux-Debian distribution for the BBB. Other Wi-Fi adapters with the same chipset will most likely work well, too. The following link provides additional information:

http://elinux.org/Beagleboard:BeagleBoneBlack#WIFI_Adapters

8 CAN BUS Interface

The CAN BUS interface is provided through the combination of the BBB's CAN controller and an ON Semiconductor transceiver (NCV7342). The controller and the transceiver are dedicated resources; therefore, the CAN BUS interface is always available. The CAN BUS is available at two connectors: J34 (normally populated) and J34A (normally not populated).

There are two placeholders for zero-Ohm resistors: R51 and R52 can be used for the implementation of standby/wake-up functionality. The two resistors provide paths to digital lines at the BBB.

9 UART Multiplexer

The UART multiplexer enables the use of the BBB's UART2 for multiple purposes. The multiplexer can be set to one of the following paths:

1. None
2. Loopback
3. External UART
4. I2C/SPI Slave Bridge
5. KNX Evaluation Board
6. XBee Module
7. USB-UART Interface

The multiplexer also provides power-off isolation through the use of 3-state output gates (U4, U6, U7, U8, U9 and U10). The BBB controls the multiplexer with three digital lines: UART_MUX_0, UART_MUX_1 and UART_MUX_2.

9.1.1 Loopback Path

This path is provided for self-test and troubleshooting purposes. Any data sent from the TX line of the UART2 port will come back to the RX line.

9.1.2 External UART Path

This path provides UART connectivity to the Hermes platform. For convenience, the UART signals are available at two connectors (J20 and J20A) with different form factors, but only one can be used at a time. The pin out of J20A follows the de facto standard of popular TTL to USB serial converter cables like FTDI's TTL-232R-3V3.

The UART signals are TTL 3.3V compatible. But because of the characteristics of the SN74LVC2G126 dual bus buffer gate, it is likely that can work for 5.0V applications. Please review the SN74LVC2G126 datasheet to verify the design for a specific application.

The SN74LVC2G126 provides power-off isolation. Therefore, it is possible to have external UART signals preset at the Hermes UART port at any time. The external signals must be within the -0.5V to 6.5V range to avoid any damage.

9.1.3 I2C/SPI Slave Bridge Path

This path enables the use of the I2C/SPI slave interface for the Hermes platform. See Section 13 for details about this interface.

9.1.4 KNX Evaluation Board Path

This path enables the use of the KNX interface for the Hermes platform. See Section 12 for details about this interface.

9.1.5 XBee Module Path

This path enables the use of the ZigBee interface for the Hermes platform. See Section 11 for details about this interface.

9.1.6 USB-UART Interface Path

This path provides USB connectivity to the Hermes platform through a virtual COM port. The USB-UART interface is implemented with a FTDI FT231XS USB-UART. FTDI provides device drivers for most operating systems. See Section 10 for details on how to enable this path.

10 USB-UART Interface

The USB-UART interface is implemented with a FTDI FT231XS USB-UART. FTDI provides virtual COM port device drivers for most operating systems and processor architectures. See the following page to download drivers and for details about support and compatibility:

http://www.ftdichip.com/Drivers/VCP.htm

This interface provides the following three uses cases:

1. Provides USB connectivity to the Hermes platform.
2. Provides connection to the BBB's debug port (UART0).
3. Provides external access to the XBee module.

Only one of these three alternatives can be used at a time.

10.1 USB Connectivity

This alternative provides access to the BBB's UART2 port. The following settings must be in place to use this alternative:

1. J16 must have two jumpers: from pin 1 to pin 3 and from pin 2 to pin 4.
2. J19 and J15 must not have any jumpers.
3. During runtime the UART multiplexer must be configured for the USB-UART interface path (UART_MUX_0=0, UART_MUX_1=1, UART_MUX_2=1).

10.2 Connection to the BBB's Debug Port

The USB-UART chip is powered by the USB bus, not by the Hermes kit. This is especially useful for this use case because it allows monitoring the BBB's debug port from the first instant after power up, thus enabling the external computer to capture all the messages from the bootloader and the Linux boot process. After boot up, the UART0 can be used as a terminal which is very useful for development and troubleshooting. There are many terminal emulation software packages available for most platforms. The following page contains links to terminal emulators that are open source and can be freely used:

https://en.wikipedia.org/wiki/Category:Free_terminal_emulators

The following settings must be in place to use this alternative:

1. J16 must have two jumpers: from pin 3 to pin 5 and from pin 4 to pin 6.
2. J19 and J15 must not have any jumpers.

10.3 External Access to the XBee Module

This use case is necessary when there is need to update the XBee module firmware. In addition to the use of the UART RX and TX signals, to update the firmware, the XBee

module requires the use of the DTR, CTS and RTS signals. And this is only possible through the USB-UART interface. The path that goes through the UART multiplexer only provides the UART RX and TX signals.

This alternative is also useful because it allows an external computer to execute the XCTU application from DIGI. The XCTU application provides utilities for configuration, development and network monitoring. For more information and to download XCTU see:

http://www.digi.com/products/xbee-rf-solutions/xctu-software/xctu

The following settings must be in place to use this alternative:

1. J15 must have three jumpers: from pin 1 to pin 2, from pin 3 to pin 4 and from pin 5 to pin 6.
2. J19 must have two jumpers: from pin 1 to pin 3 and from pin 2 to pin 4.
3. J16 must not have any jumpers.
4. The XBee module is powered by the BBB. Therefore the BBB must be on during firmware updates and during the XCTU application operation.
5. The RESET signal must be active high in order to enable the XBee module. This can be accomplished with the following commands:
    a. `echo 22 > /sys/class/gpio/export`
    b. `echo out > /sys/class/gpio/export/gpio22/direction`
    c. `echo 1 > /sys/class/gpio/export/gpio22/value`
6. The UART multiplexer must not be configured for the XBee path. This can be accomplished with the following commands:
    a. `echo 66 > /sys/class/gpio/export`
    b. `echo 26 > /sys/class/gpio/export`
    c. `echo 27 > /sys/class/gpio/export`
    d. `echo out > /sys/class/gpio/export/gpio66/direction`
    e. `echo out > /sys/class/gpio/export/gpio26/direction`
    f. `echo out > /sys/class/gpio/export/gpio27/direction`
    g. `echo 0 > /sys/class/gpio/export/gpio66/value`
    h. `echo 0 > /sys/class/gpio/export/gpio26/value`
    i. `echo 0 > /sys/class/gpio/export/gpio27/value`

WARNING: The Hermes board must be powered up all the time while there is an external computer connected to Hermes USB port. This is because the USB-UART interface is powered by the USB bus, and there is no power-off protection on the XBee module side. MALFUNCTION AND HARDWARE DAMAGE MAY OCCUR.

WARNING: The UART multiplexer must not be configured for the XBee path because it will cause a short to the USB-UART and XBee module lines. MALFUNCTION AND HARDWARE DAMAGE WILL OCCUR.

11 XBee Module

This XBee module implements the ZigBee protocol. This module can be operated in two modes:

1. From the BBB's UART2 through the UART multiplexer. See 9.1.5.
2. From an external computer through the USB-UART interface. See 10.3.

Several signals from the XBee module are routed to the J27 connector, which is normally not populated.

12 KNX Evaluation Board

An ON Semiconductor KNX NCN5130 evaluation board is integrated with Hermes. It communicates with the BBB's UART2 through the UART multiplexer. See 9.1.4 for details.

The signals TREQ, MODE1 and MODE2 are connected to ground. Therefore the NCN5130 can only be operated through the serial port. The analog mode and the SPI Master interface are not available.

Several signals from the KNX evaluation board are routed to the J21 connector, which is normally not populated.

12.1 Configuration Jumpers

The SCK, CSB and XCLKC signals are routed to the J23 connector. These signals can be connected to ground or to 3.3V from the KNX module using jumpers to the J22 or J24 connectors. SCK and CSB are used to configure the serial port and XCLKC to configure the clock frequency. See the NCN5130 datasheet for details.

12.2 Analog Signals

The 3.3V regulator output and the signal ANAOUT are connected to BBB's analog inputs using voltage dividers. Monitoring these signals from the BBB is useful for KNX operation, troubleshooting and development. The ANAOUT can be configured to output any of seven possible nets inside the NCN5130. See the NCN5130 datasheet for details.

12.3 Digital Signals

Signals SAVEB and TRIG are connected to a power-off protection switch (U13). From this point they can be connected to digital lines at the BBB using zero-Ohm resistors. SAVEB is connected by default and TRIG is not connected by default. Monitoring these signals from the BBB is useful for KNX operation, troubleshooting and development.

13 I2C/SPI Slave Interface

Hermes provides an I2C/SPI slave interface through the use of a UART–I2C/SPI bridge (NXP SC16IS740). The UART side of the bridge can be connected to the BBB UART2 port through the UART multiplexer. See 9.1.3 for details. The bridge can be configured either for SPI or for I2C, but only one at a time. The configuration is done through the use of jumpers and must be done while the Hermes kit is powered off.

WARNING: Configuring the bridge while the Hermes kit is on could result in hardware damage depending on the connections at the time.

The I2C and SPI signals are available at two connectors (J37 and J37A) for the convenience of the user. J37 is normally populated, and J37A is not.

13.1 SPI Configuration

1. J10, J35 and J38 must not have any jumpers.
2. J36 must have a jumper between pin 2 and pin 3.

13.2 I2C Configuration

1. J10 must have a jumper between pin 1 and pin 2.
2. J35 can be used to configure the I2C address. A0 and A1 can be independently connected to either VDD_3V3B (through 10K Ohm pull-up resistors) or to GND. See the SC16IS740 datasheet for details.
3. J36 and J38 can be used to provide 4.7K Ohm pull-up resistors to SCL and SDA in case the I2C master does not have them already. Use this feature with caution since these pull-ups can end up damaging an I2C master with no power-off protection.

13.3 IRQ Line

The bridge's IRQ line can be connected to the BBB using a zero-Ohm resistor (R82). This can be useful in the implementation of an interruption based API as opposed to a polling based API.

13.4 I2C Loopback

J41 can be used to create an I2C loopback from the bridge's I2C slave to the BBB's I2C1 master. To enable the loopback, place two jumpers from pin 1 to pin 2 and from pin 3 to pin 4. Under normal operation, there should not be any jumpers placed at J41. Finally, Hermes already provides the pull-ups for I2C1, so there is no need to place jumpers at J36 and J38.

13.5 SPI Loopback

J33 can be used to create an SPI loopback from the bridge's SPI slave to the BBB's SPI1 master. To enable the loopback, place four jumpers from pin 1 to pin 2, pin 3 to pin 4, pin 5 to pin 6 and pin 7 to pin 8.

14 Default Jumper Settings

Table 1 shows the specified default jumper settings and Figure 5 shows pictures with the default settings.

Table 1 Default jumper settings

Connector(s)	Jumper Settings
J10, J25, J38	Jumper between pin 1 and the other position floating
J15	Jumper between pin 2 and the other position floating Jumper between pin 4 and the other position floating Jumper between pin 6 and the other position floating
J16	Jumper between pin 3 and pin 5 Jumper between pin 4 and pin 6
J22, J23, J24	Jumper between pin J22-1 and J23-1 Jumper between pin J22-2 and J23-2 Jumper between pin J22-3 and J23-3
J28	Jumper between pin 1 and the other position floating Jumper between pin 3 and the other position floating Jumper between pin 5 and the other position floating Jumper between pin 7 and the other position floating
J35	Jumper between pin 3 and the other position floating Jumper between pin 4 and the other position floating
J36	Jumper between pin 2 and pin 3
J41	Jumper between pin 1 and the other position floating Jumper between pin 3 and the other position floating

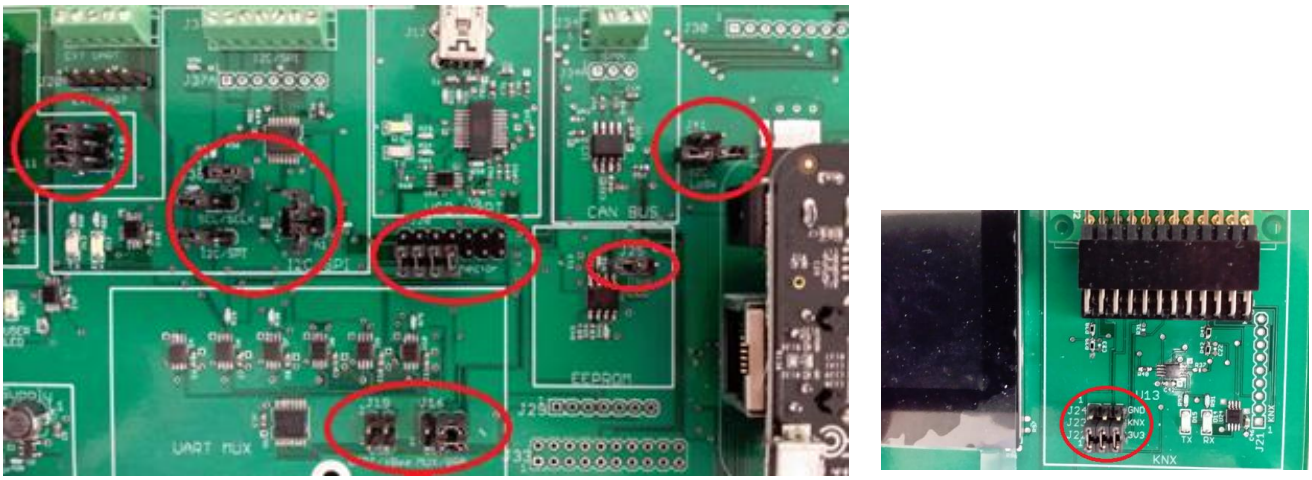

Figure 5 Default jumper settings

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