AbioCard model A and B

I/O Cards

User Manual

March 2015

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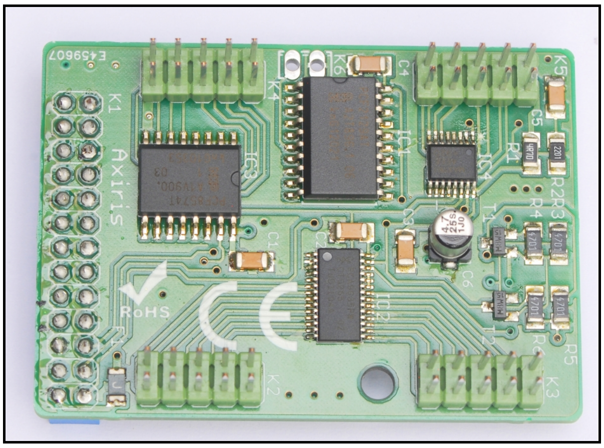
Revision History

Date	Authors	Description
2012-08-20	Peter S'heeren	Initial release.
2012-09-09	Peter S'heeren	Updated for new revision 2 of Raspberry Pi. Second release.
2012-09-10	Peter S'heeren	Updated for latest software. Third release.
2012-09-17	Peter S'heeren	Fourth release.
2012-10-21	Peter S'heeren	Updated for model A and model B of the AbioCard. Updated for latest software. Fifth release.
2012-12-14	Peter S'heeren	Updated for latest software. Sixth release.
2013-01-28	Peter S'heeren	Updated for latest software (issued 2013-01-26). Updated for i2c-dev support. Seventh release.
2013-09-17	Peter S'heeren	Updated for latest software (issued 2013-09-17). Eighth release.
2014-07-11	Peter S'heeren	Updated for latest software (issued 2014-07-07). Added support for AxiCat. Ninth release.
2015-03-02	Peter S'heeren	Updated for latest software (issued 2015-02-28). Added support for Raspberry Pi model 2. Tenth release.

1 Features



- Battery backed up real-time clock and calendar with integrated temperature compensated crystal oscillator and a 32.768 kHz quartz crystal.
- 8 general-purpose quasi-bidirectional I/O lines, 5 V levels.
- *Model A* - 16 output channels providing 8-bit pulse-width modulation (PWM) at 97 kHz with LED drive capability, 10 mA source, 25 mA sink, 5 V levels.
- *Model B* - 16 output channels providing 12-bit pulse-width modulation (PWM) output channels at about 40 to 1000 Hz with LED drive capability, 10 mA source, 25 mA sink, 5 V levels.
- Low-power, 12-bit, 8-channel analog-to-digital converter chip featuring internal track/hold, voltage reference, and clock.
- Polyfuse on the 5V line for preventing damage to the computer.
- Compact footprint due to the use of SMD components.
- Free software.

Applications include:

- Home automation (domotics).
- Industrial automation.
- Multimedia (ambient effect, audio spectrum display, ...).
- RGB LED control.
- Educational purposes.
- *Model B* - Motor and servo control.

2 Technical Specifications

Dimensions	55 mm x 40 mm x 18 mm (W x D x H)
Weight	16 g (without battery)
RTC backup power	10 years

3 Installation

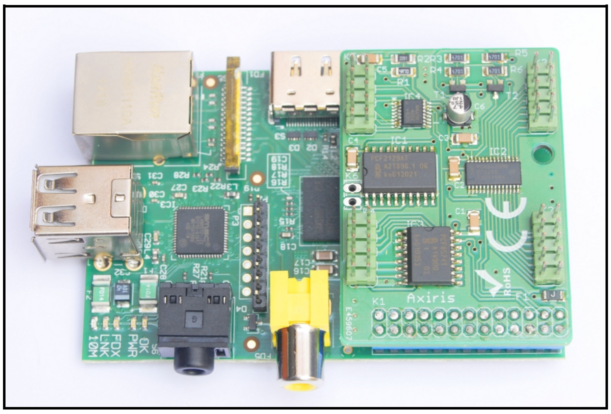
AbioCard

First of all, place a CR2032 battery in the battery holder on the backside of the AbioCard.

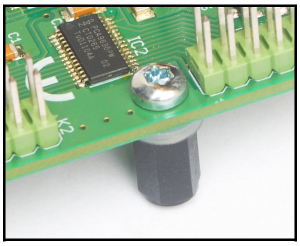
Note that when no battery is present, the AbioCard will work except the real-time clock won't keep the time when the system is powered down.

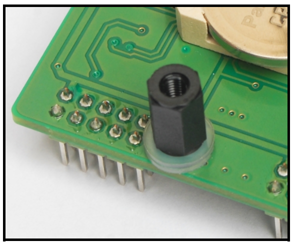
Use with Raspberry Pi model A and B

The AbioCard has a 2x13 pin female header that fits perfectly on your Raspberry Pi computer. Be sure you connect the AbioCard in such a way it hovers over the computer as shown in the picture to the right.



A dedicated enclosure for the combo is available. If you prefer not to use the dedicated enclosure, it's recommended to mount the spacer that came with the AbioCard between the AbioCard and the computer. The AbioCard provides a mounting hole for this purpose. Use the included nylon washers to adjust for optimal height.

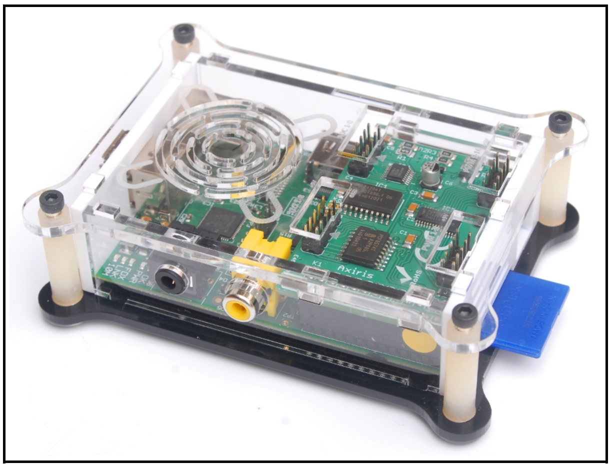




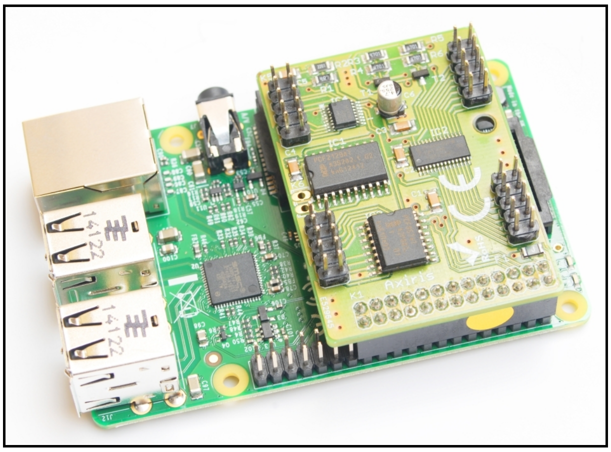
Whether you use the enclosure or the spacer, it's that the AbioCard's backside can't touch the computer directly. When mounting, you've to prevent the AbioCard's lithium battery from touching components on the computer PCB.

An enclosure specifically designed for the combo is available.

The enclosure comes with holes on top that allow you to connect external hardware to the 2x5 pin female headers. You can use jumper wires and ribbon cable connectors for this purpose.



Use with Raspberry Pi model A+, B+ and 2



The AbioCard fits on Raspberry Pi model A+, Raspberry Pi model B+, and Raspberry Pi model 2.

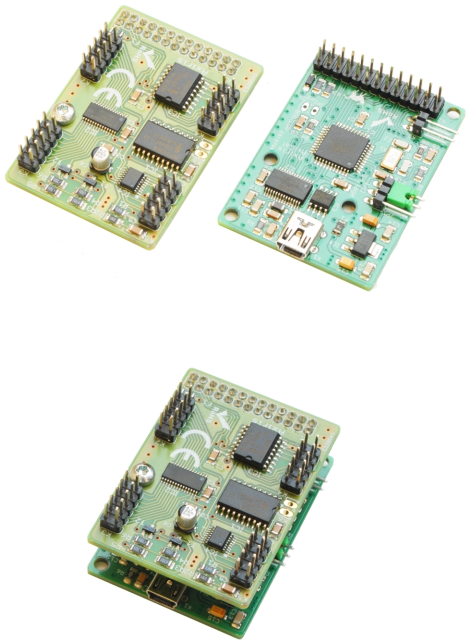
The 40-pin header on these computers is an extension of the 26-pin header that's found on model A and model B. Be sure the AbioCard is mounted as shown in the picture to the right.

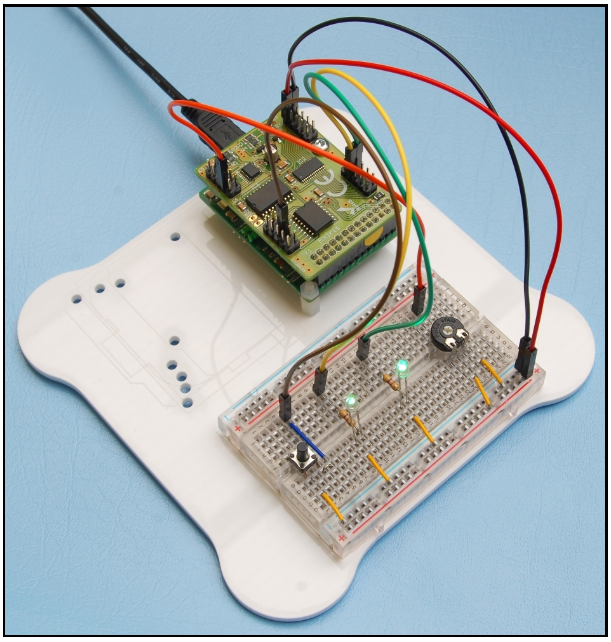
You've to prevent the AbioCard's lithium battery from touching components on the computer PCB.

Note that you can't mount the spacer that came with the AbioCard; there's a component on the computer that prevents successful positioning of the spacer. A good way to keep the AbioCard and computer apart is sticking one or two bumpers between the bottom of the AbioCard and the top of the computer's HDMI connector.

Use with AxiCat

With the help of the AxiCat, you can connect an AbioCard model A or B to any computer that's capable of running the AbioCard software.



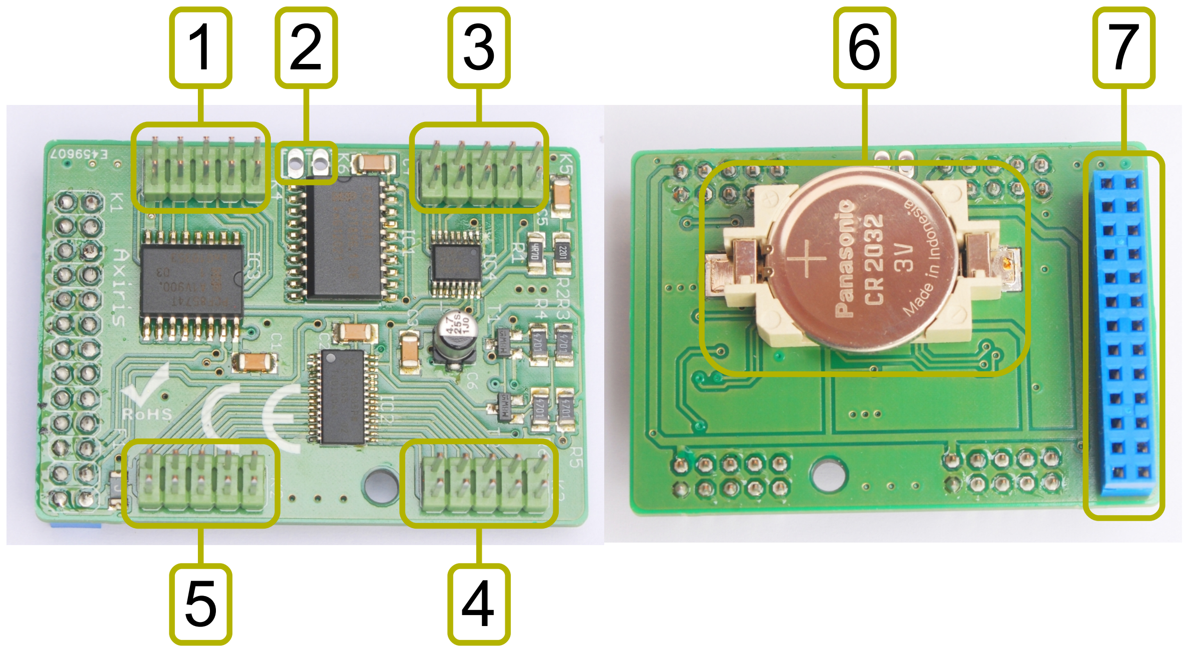


Make sure the jumper (JP1) is set to 3.3 V operation as shown in the picture above!

It's important that the AbioCard's backside can't touch the AxiCat directly. Mount the spacer that came with the AbioCard between the AbioCard and the AxiCat. Both the AbioCard and the AxiCat provide a mounting hole for this purpose. Use the included nylon washers to adjust for optimal height.

4 Interfacing

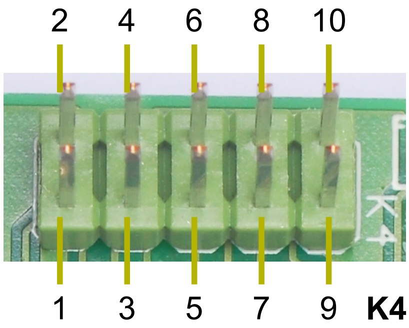
Board Overview



Mark	Label	Description	
1	K4	PCF8574 general-purpose I/O connector	
2	K6	PCF2129A timestamp input	
3	K5	MAX11614 analog inputs connector	
4	K3	*Model A*	PCA9635 LED driver pins LED8-LED15 connector
		Model B	PCA9685 LED driver pins LED8-LED15 connector
5	K2	*Model A*	PCA9635 LED driver pins LED0-LED7 connector
		Model B	PCA9685 LED driver pins LED0-LED7 connector
6		RTC backup power battery, 3 V type CR2032	
7	K1	I/O female connector	

General-Purpose I/O Connector (K4)

Mark	Description
1	I/O channel 0
2	I/O channel 1
3	I/O channel 2
4	I/O channel 3
5	I/O channel 4
6	I/O channel 5
7	I/O channel 6
8	I/O channel 7
9	GND
10	5 V output



The I/O channels are quasi-bidirectional. The direction is determined by the software:

- When used as input, software must set the output pin to HIGH.
- When used as output, software writes any value to the pin.

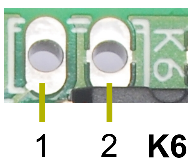
IMPORTANT!

The AbioCard doesn't incorporate pull-up resistors on the I/O pins of the PCF8574. If you intend to use an I/O channel as output, and you want to read back the current output logic level, then it is recommended to connect an appropriate pull-up resistor to the pin, else software may read back logic zero rather than the actual state, especially when current is being drawn from the pin.

Refer to the PCF8574 datasheet for more information.

Timestamp Input (K6)

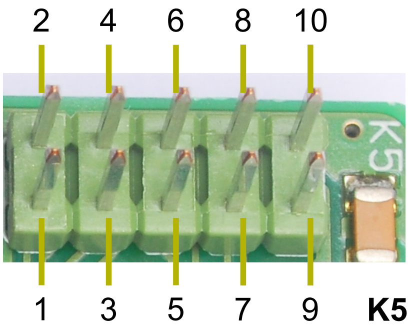
Mark	Description
1	PCF2129A $\overline{\text{TS}}$ input
2	GND



Refer to the PCF2129A datasheet for more information about the timestamp functionality.

Analog Inputs Connector (K5)

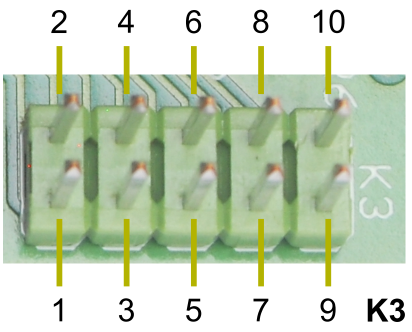
Mark	Description
1	Analog input 0
2	Analog input 1
3	Analog input 2
4	Analog input 3
5	Analog input 4
6	Analog input 5
7	Analog input 6
8	Analog input 7
9	GND
10	5 V output



Connector K5 exposes the 8 analog input pins of the MAX11614. This chip offers a variety of settings for using the analog inputs. Refer to the MAX11614 datasheet for more information.

LED Driver Connector (K3)

Mark	Description
1	LED driver pin LED8
2	LED driver pin LED9
3	LED driver pin LED10
4	LED driver pin LED11
5	LED driver pin LED12
6	LED driver pin LED13
7	LED driver pin LED14
8	LED driver pin LED15
9	GND
10	5 V output



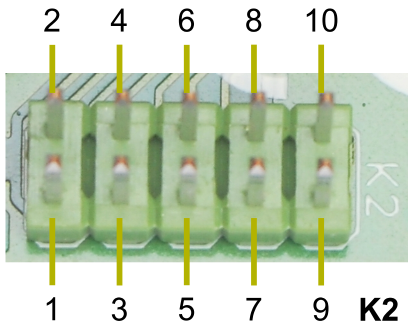
Connector K3 exposes the last eight LED outputs of the LED driver.

Model A - Refer to the PCA9635 datasheet for more information.

Model B - Refer to the PCA9685 datasheet for more information.

LED Driver Connector (K2)

Mark	Description
1	LED driver pin LED0
2	LED driver pin LED1
3	LED driver pin LED2
4	LED driver pin LED3
5	LED driver pin LED4
6	LED driver pin LED5
7	LED driver pin LED6
8	LED driver pin LED7
9	GND
10	5 V output



Connector K2 exposes the first eight LED outputs of the LED driver.

Model A - Refer to the PCA9635 datasheet for more information.

Model B - Refer to the PCA9685 datasheet for more information.

5 I2C Bus

Slave Addresses

The I2C bus on the AbioCard interconnects your AxiCat or Raspberry Pi computer with a set of I2C slave devices. Each slave device responds to one or more I2C addresses. The slave addresses are:

Address	Slave Device	
1010001b	PCF2129A real-time clock	
0100111b	PCF8574 8-bit I/O expander	
0110011b	MAX11614 analog-to-digital converter	
0001000b	*Model A*	PCA9635 LED driver
1001000b	*Model B*	PCA9685 LED driver
1110000b	PCA9635/PCA9685 all devices "LED All Call" address	
0000011b	PCA9635/PCA9685 all devices SWRST (software reset)	

Bus Speed

The AbioCard supports a maximum bus speed of 100 kHz.

Real-time Clock

The PCF2129A is a real-time clock and calendar with an integrated temperature compensated crystal oscillator and a 32.768 kHz quartz crystal. The PCF2129A has a backup battery switch-over circuit, a programmable watchdog function, a timestamp function, and many other features.

The board has a holder for a CR2032 battery that functions as backup power for the PCF2129A.

8-bit I/O Expander

The PCF8574 is an 8-bit I/O expander. The outputs feature a high current drive capable of directly driving LEDs.

The I/O channels are quasi-bidirectional. Refer to the PCF8574 datasheet for more information.

Analog-to-Digital Converter

The MAX11614EEE+ is a low-power, 12-bit, 8-channel analog-to-digital converter chip featuring internal track/hold (T/H), voltage reference, and clock.

Model A - LED Driver

The PCA9635 is an 8-bit PWM LED driver optimized for red/green/blue/amber (RGBA) color mixing applications.

The PCA9635 uses a frequency of 97 kHz for PWM control. An additional frequency of 190 Hz and a adjustable frequency of about 24 Hz to 0.01 Hz provide dimming and blinking features.

Model B - LED Driver

The PCA9685 is a PWM LED driver optimized for red/green/blue/amber (RGBA) color mixing applications.

The PCA9685 uses a frequency of about 40 to 1000 Hz for PWM control enabling it to drive motors and servos.

The on and off times of the PWM output signal can be programmed for each channel individually. This design aids in minimizing current surges.

6 Software

Software Revision

This document corresponds with the AbioCard software issued 2015-02-28.

Overview

The AbioCard comes with a number of software programs that run on Linux and Windows operating systems.

This document describes commands entered at the command prompt of Linux. When entering a command at the prompt of your personal log in, the document uses the $ notation. For example:

```
$ sudo ./abiocardtime -p
```

A command entered at the prompt of the root log in is written with the # notation. For example:

```
# ./abiocardtime -u
```

This document describes commands entered at the command prompt of Windows with the > notation. For example:

```
> abiocardserver.exe -p 5678 -axicat \\.\COM4
```

Accessing I2C from Software

Software has several ways of accessing the I2C-based AbioCard on your hardware:

- Direct I/O (available on Raspberry Pi computers running Linux).
- Using the Linux i2c-dev interface (available on Linux systems).
- Using the AxiCat board (Linux and Windows systems).

AxiCat

The AxiCat board is USB-based. The board enables you to connect your AbioCard to a variety of computer systems that run Linux or Windows.

The AxiCat incorporates an FT245 chip and is enumerated as a USB-to-serial adapter. The operating system assigns a serial path to the AxiCat which you pass as an argument to the software.

AxiCat I/O may or may not require root privileges in Linux. It depends on the permissions the system forces on serial paths. If you're not sure, you're advised to run the software as root.

Direct I/O

Direct I/O means the programs that run on your Raspberry Pi computer directly communicate with the AbioCard from user-mode using the first serial controller (BSC0) or the second serial controller (BSC1) on the BCM2835/2836 application processor.

Obviously using direct I/O is appropriate when no I2C driver is loaded, or at least the BSC that connects to the AbioCard is not under control of any I2C driver.

Direct I/O requires root privileges.

IMPORTANT!
Do not force the programs to use direct I/O if I2C drivers are present. Doing so may disrupt the proper working of the I2C drivers and subsequently hang or crash the operating system.

i2c-dev Interface

I2C driver support in Linux includes a driver named i2c-dev. This driver offers a file interface to the I2C adapters from user-mode through files in the **/dev** directory. These files are named **/dev/i2c-<n>** where **<n>** is a number starting from zero:

- **/dev/i2c-0** – i2c-dev interface for BSC0.
- **/dev/i2c-1** – i2c-dev interface for BSC1.

Normally access to these files requires root privileges.

Whether or not the i2c-dev interface is present depends on various settings and attributes, including the version of the Linux kernel, presence of the device tree feature, and blacklisting of drivers. Please refer to the Raspberry Pi documentation for more information.

Revision of your Raspberry Pi Computer

There are several revisions of the computer. The GPIO pins are not compatible between these revisions. Although the incompatibility doesn't affect the AbioCard hardware, it does affect the software as follows:

- Older revisions: The GPIO header pins 3 and 5 are wired to BSC0.
- Newer revisions: The GPIO header pins 3 and 5 are wired to BSC1.

Older revisions only include Raspberry Pi model A and model B. Model A+, model B+ and model 2 are always newer revisions.

Please refer to the Raspberry Pi documentation for more information.

The programs **abiocardtime** and **abiocardserver** auto-detect the revision of the computer and as such the BSC to use. They also provide command line parameters for overruling the detected BSC.

Program **abiocardgui** provides arrows for selecting the BSC.

If you're not sure about the revision and which BSC is wired to GPIO header pins 3 and 5, you can proceed as follows. Install the **abiocardgui** package on your Raspberry Pi with the AbioCard installed. Run the program **abiocardgui**. Depending on the I2C interface, proceed with one of the following steps:

- Direct I/O: Connect with either BSC until connection succeeds. The selected BSC then is the one wired to GPIO header pins 3 and 5.
- i2c-dev interface: Select i2c-dev. Enter **/dev/i2c-<n>** where **<n>** is **0** or **1** and try connecting. If the connection is successful the number indicates the BSC.

Program abiocardtime

This program runs on Linux systems. It only runs for a very short time. Its main purpose is to read the current date and time from the RTC on the AbioCard and update the operating system's software clock accordingly.

The program can't set the operating system's software clock when the real-time clock reports the power-up detected state. You'll need to set the actual date and time in the real-time clock first. You can use the **abiocardgui** program for this purpose or run the **abiocardtime** program at the command prompt with the "-s" parameter.

The program is expected to run once during Linux startup. Once Linux is running, it's recommended to execute the program periodically in order to keep the operating system's software clock in line with the more accurate real-time clock on the AbioCard.

Executable

Since the program can run on various Linux systems, you've to build the executable for your specific Linux installation.

To build the program in Linux:

```
$ make -f abiocardtime.mk
```

To clean up the intermediate build files:

```
$ make -f abiocardtime.mk clean
```

If you follow the installation procedure for the **abiocard** package, the installation script will build the program automatically (unless the executable already exists) and add it to the cron table of the root user.

Command Line

Parameter	Description
-s <u>STRING</u>	Set system date and time from the RTC. Example <u>STRING</u>: "2014-07-07 12:18:48".
-u	Update the system time using the RTC.
-p	Poll the RTC and print.
-axicat <u>PATH</u>	Select the AxiCat with the given serial path as the interface. Example <u>PATH</u>: /dev/ttyUSB0
-bsc <u>n</u>	This parameter forces the use of direct I/O. Value n=0..1 decimal. The value selects the BSC.
-dev <u>FILE</u>	This parameter forces the use of the i2c-dev interface. Example <u>FILE</u>: /dev/i2c-0

If no interface is specified, the program assumes it's running on a Raspberry Pi computer and automatically tries to detect the I/O interface to use and the target BSC. If this is not the intended behavior, use the **-axicat**, **-bsc** or **-dev** parameter to overrule the detection.

When multiple of the following commands are specified, they're executed in this order:

-s STRING ► **-u** ► **-p**

Example Invocations of the Program

Use automatic detection of the I/O interface on a Raspberry Pi computer and update the system time using the RTC:

```
# ./abiocardtime -u
```

Deploy an AxiCat with AbioCard in Linux, update the system time using the RTC:

```
$ ./abiocardtime -u -axicat /dev/ttyUSB0
```

Set the date and time in the RTC of an AbioCard plugged into an AxiCat:

```
$ ./abiocardtime -s "2014-07-07 12:18:48" -axicat /dev/ttyUSB0
```

Program abiocardserver

This server program runs on Linux and Windows systems. The server supports the hardware configuration implemented by the **abiocard** module.

The server offers two modes of communication with the AbioCard:

- Network mode: a socket interface enables communication over the network.
- Standard input and output mode: another process communicates with the AbioCard.

The server uses a simple protocol for accepting commands and generating responses in human-readable format using the ASCII character set. There's a timeout on incoming characters, specified in seconds. When the server doesn't receive any character for the specified time, it'll close the connection with the client. The timeout is not applicable when standard input and output are used.

Network Mode

The dearest client of the server is the **abiocardgui** program.

You can use a terminal program (like Putty) for sending commands manually to the server. Be sure to specify a timeout value big enough so the server won't shut down your connection should you type too slow. You may as well specify the maximum timeout value for the purpose of using a terminal program.

The server program works with one AbioCard, hence it will accept one incoming socket connection only. If you want to provide access to more than one AbioCard from the same computer, you can run multiple instances of the server, one instance for each AbioCard.

The server is designed to run in the background. When you require the permanent services of the program, it's recommended to execute **abiocardserver** during Linux startup.

The server will only interact with the AbioCard when it has accepted an incoming connection. As such it can safely be invoked alongside the **abiocardtime** program during Linux startup without the risk of interfering with the proper execution of the **abiocardtime** program.

Standard Input and Output Mode

This mode allows another running process to directly write commands to the server and read responses back on the same system.

Typical use-cases include manually typing in and sending commands from the console, piping files with commands to the server, and controlling the AbioCard from a scripting language.

Executable

<u>Linux</u>

Since the program can run on various Linux systems, you've to build the executable for your specific Linux installation.

To build the program:

```
$ make -f abiocardserver.mk
```

To clean up the intermediate build files:

```
$ make -f abiocardserver.mk clean
```

If you follow the installation procedure for the **abiocard** package, the installation script will build the program automatically (unless the executable already exists) and add it to the cron table of the root user.

Windows

The executable for Windows operating systems is included in the **abiocard** package.

Command Line

Parameter	Description
-h	Print help.
-console	Open a console window. *Windows only.*
-p n	Select network mode. The value specifies the port number the server must listen to. Value n=1..65535 decimal.
-t n	Time-out value between two incoming characters. Value n=5..65535 decimal (seconds). This parameter is optional. The default value is 30 seconds.
-stdio	Select standard input and output mode.
-axicat PATH	Select the AxiCat with the given serial path as the interface. Example PATH in Linux: /dev/ttyUSB0 Example PATH in Windows: \\.\COM4
-bsc n	Select the BSC. Value n=0..1 decimal. This parameter forces the use of direct I/O and overrules the detected BSC value. *Linux only.*
-dev FILE	This parameter forces the use of the i2c-dev interface. Example FILE: /dev/i2c-0 *Linux only.*

Parameter **-p** or **-stdio** must be specified.

In Linux, if no interface is specified, the program assumes it's running on a Raspberry Pi computer and automatically tries to detect the interface to use and the target BSC. If this is not the intended behavior, use the **-axicat**, **-bsc**, **-dev** or **-stdio** parameter to overrule the detection.

The Windows version of the program only supports the AxiCat interface.

Hint: If you want a console window, specify **-console** as the first parameter. Doing so will always bring up the console even if there's an error in the command line.

Example Invocations of the Program

Use automatic detection of interface on a Raspberry Pi computer. The server listens to port 5678. Time-out value is set to 5 seconds. Command:

```
$ sudo ./abiocardserver -p 5678 -t 5
```

By using standard input and output, you can type commands in the shell and look at the resulting responses:

```
$ sudo ./abiocardserver -stdio
HI                                          You enter this command
HI17                                        The program's response
EW48                                        You enter this command
ER                                          You enter this command
ER48                                        The program's response
CR                                          You enter this command
CR13091701113501                            The program's response
```

Send an EOF character to close the program. In Linux, press CTRL-D. In Windows, press CTRL-Z followed by ENTER.

Instead of typing the commands in the shell, one may spawn the program from another process and send and receive commands and responses over standard input and output to control the AbioCard programmatically.

By using pipes, you can stream a file containing commands into the program and stream out the results into another file:

```
$ sudo ./abiocardserver -stdio < commands.txt > responses.txt
```

Typing commands in the shell and sending them to an AbioCard with an AxiCat on a Windows system:

```
> abiocardserver.exe -stdio -axicat \\.\COM10
$ sudo ./abiocardserver -stdio
CR                                          You enter this command
CR13091701113501                            The program's response
```

Protocol

The server accepts commands and returns a response if defined. The server never sends a response autonomously, it only responds to individual commands.

The server will only respond to a command when the command was correctly formatted, was executed successfully, and a response is defined.

Both commands and responses are composed of a string of ASCII characters concluded by an end-of-line character. The server recognizes LF (10) and CR (13) as end-of-line marker. A response from the server is always concluded with a LF (10).The following formatting is used in the description of the commands and responses:

Format	Description
CR	Literal characters i.e. character 'C' followed by character 'R'.
ABC	These characters containing specific information as explained.
[ABC]	An array of these characters containing specific information as explained.
<EOL>	End-of-line marker, either LF (10) or CR (13).
<LF>	End-of-line marker LF (10).
<none>	No response.

CR – Clock Read

Command	**CR<EOL>**	
Response	**CR**YYMMDDhhmmsspb**<LF>**	
	YY	The year, 00..99 decimal, meaning year 2000..2099.
	MM	The month, 01..12 decimal, meaning January..December.
	DD	The day, 01..31 decimal.
	hh	The hour, 00..23 decimal.
	mm	The minute, 00..59 decimal.
	ss	The second, 00..59 decimal.
	p	The power-up detected flag: ▪ =0: No power-up detected, date and time fields are valid. ▪ =1: Power-up detected, **date and time fields are invalid**.
	b	The battery low flag, either 0 or 1.

This command reads ("polls") the real-time clock.

The date and time field are valid only when no power-up is detected. To clear the power-up detected state, data and time must be set by sending a **CW** command.

The battery is deemed low when either the battery is running out or when there's no battery at all.

CW – Clock Write

Command	**CW**YYMMDDhhmmss**<EOL>**	
	YY	The year, 00..99 decimal, meaning year 2000..2099.
	MM	The month, 01..12 decimal, meaning January..December.
	DD	The day, 01..31 decimal.
	hh	The hour, 00..23 decimal.
	mm	The minute, 00..59 decimal.
	ss	The second, 00..59 decimal.
Response	**<none>**	

This command writes the date and time to the real-time clock.

If successful, the power-up detected state will be cleared.

ER – I/O Expander Read

Command	**ER<EOL>**	
Response	**ER**XX**<LF>**	
	XX	8-bit value read from the I/O expander inputs, 00..FF hexadecimal.

This command reads the state of the inputs of the I/O expander chip and responds with the resulting value.

EW – I/O Expander Write

Command	**EW**XX**<EOL>**	
	XX	8-bit value to write to the I/O expander outputs, 00..FF hexadecimal.
Response	**<none>**	

This command writes the 8-bit value to the outputs of the I/O expander.

AR – ADC Read

Command	**AR<EOL>**	
Response	**AR**V00V01V02V03V04V05V06V07**<LF>**	
	V00	Converted value of analog input 0, 000..FFF hexadecimal.
	V01	Converted value of analog input 1, 000..FFF hexadecimal.
	V02	Converted value of analog input 2, 000..FFF hexadecimal.
	V03	Converted value of analog input 3, 000..FFF hexadecimal.
	V04	Converted value of analog input 4, 000..FFF hexadecimal.
	V05	Converted value of analog input 5, 000..FFF hexadecimal.
	V06	Converted value of analog input 6, 000..FFF hexadecimal.
	V07	Converted value of analog input 7, 000..FFF hexadecimal.

This command converts all eight analog inputs and responds with the values.

PR – PWM Read

Command	**PR**SSCC**<EOL>**	
	SS	Start index, 00..10 hexadecimal.
	CC	Count, 01..11 hexadecimal.
Response	**PR**SSCC[XX]**<LF>**	
	SS	Start index, 00..10 hexadecimal.
	CC	Count, 01..11 hexadecimal.
	[XX]	Array of register values, 00..FF hexadecimal. The count field indicates the number of array elements.

This command reads registers in the PCA9635 LED driver.

Indexes 0 to 15 correspond with registers PWM0 to PWM15, index 16 with register GRPPWM in the LED driver chip.

PW – PWM Write

Command	**PW**SSCC[XX]**<EOL>**	
	SS	Start index, 00..10 hexadecimal.
	CC	Count, 01..11 hexadecimal.
	[XX]	Array of register values, 00..FF hexadecimal. The count field indicates the number of array elements.
Response	**<none>**	

This command writes registers in the PCA9635 LED driver.

Indexes 0 to 15 correspond with registers PWM0 to PWM15, index 16 with register GRPPWM in the LED driver chip.

QP – PWM2 Read Prescaler

Command	**QP<EOL>**	
Response	**QP**XX**<LF>**	
	XX	8-bit value read from the prescaler register, 00..FF hexadecimal.

This command reads the prescaler register in the PCA9685 and responds with the resulting value.

QQ – PWM2 Write Prescaler

Command	**QQ**XX**<EOL>**	
	XX	8-bit value to write to the prescaler register, 00..FF hexadecimal.
Response	**<none>**	

This command writes the 8-bit value to the prescaler register in the PCA9685.

Note that the PCA9685 forces the minimal value that can be written to the prescaler is 3. So if you issue a value between 0..2, the hardware will write 3 to the prescaler register. You can always read back the actual prescaler register value using the **QP** command.

QR – PWM2 Read

Command	QRSSCC<EOL>			
	SS	Start index, 00..0F hexadecimal.		
	CC	Count, 01..10 hexadecimal.		
Response	QRSSCC[V000V001]<LF>			
	SS	Start index, 00..0F hexadecimal.		
	CC	Count, 01..10 hexadecimal.		
	[...]	Array of value pairs. The count field indicates the number of pairs.		
		V000	Settings of the ON state of the PWM output signal, 0000..1FFF hexadecimal. This value is composed of bit fields:	
			bit 15..13	Zero.
			12	Always ON yes/no (1/0).
			11..0	ON time (0..4095).
		V001	Settings of the OFF state of the PWM output signal, 0000..1FFF hexadecimal. This value is composed of bit fields:	
			bit 15..13	Zero.
			12	Always OFF yes/no (1/0).
			11..0	OFF time (0..4095).

This command reads the PWM registers of one or more channels in the PCA9685 LED driver.

QW – PWM2 Write

Command	`QWSSCC[V000V001]`<EOL>			
	SS	Start index, 00..0F hexadecimal.		
	CC	Count, 01..10 hexadecimal.		
	[...]	Array of value pairs. The count field indicates the number of pairs.		
		V000	Settings of the ON state of the PWM output signal, 0000..1FFF hexadecimal. This value is composed of bit fields:	
			bit 15..13	Zero.
			12	Always ON yes/no (1/0).
			11..0	ON time (0..4095).
		V001	Settings of the OFF state of the PWM output signal, 0000..1FFF hexadecimal. This value is composed of bit fields:	
			bit 15..13	Zero.
			12	Always OFF yes/no (1/0).
			11..0	OFF time (0..4095).
Response	<none>			

This command writes the PWM registers of one or more channels in the PCA9685 LED driver.

Note that the "always OFF" bit overrules the "always ON" bit. When both bits are set to one, the PCA9685 will turn off the PWM channel.

HI – Hardware Information

Command	`HI`<EOL>	
Response	`HIXX`<LF>	
	XX	Hardware presence bit mask, 00..FF hexadecimal. Bit 0: Real-time clock is present yes/no (1/0). Bit 1: I/O expander is present yes/no (1/0). Bit 2: Analog-to-digital converter is present yes/no (1/0). Bit 3: PCA9635 LED driver is present yes/no (1/0). Bit 4: PCA9685 LED driver is present yes/no (1/0). Bit 5..7: Reserved (0).

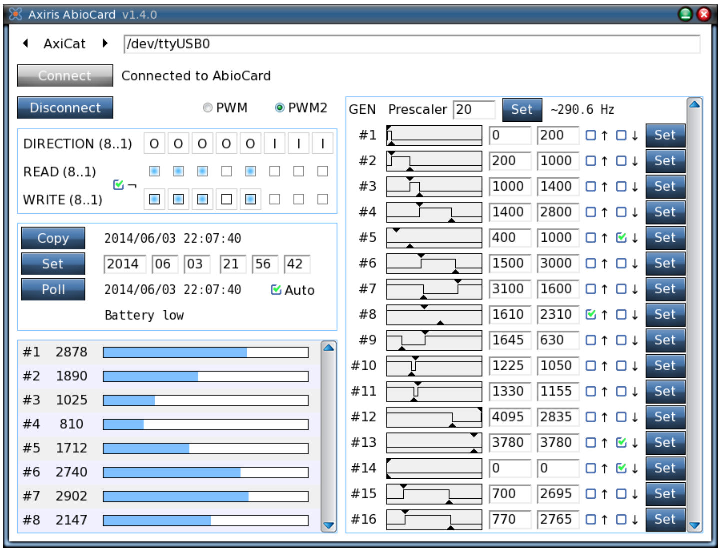
This command queries the hardware information gathered during initialization of the AbioCard.

QU – Quit the server

Command	`QU`<EOL>
Response	<none>

When the server receives this command, it immediately closes the connection, shuts down the port it's listening to, and terminates.

Program abiocardgui



The **abiocardgui** program is a graphical front-end application that visualizes the state of the AbioCard and allows the user to interact with the AbioCard.

The program runs on a variety of systems including Linux for x86 and ARM, and Windows 2000 and later.

When the program runs locally on your Raspberry Pi computer, it can directly communicate with the AbioCard.

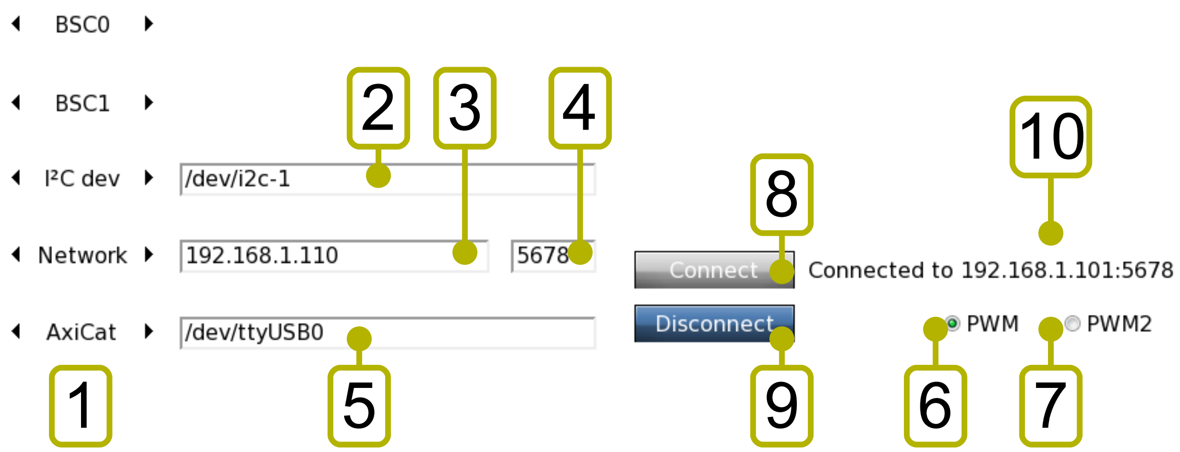
You can mount the AbioCard on an AxiCat and connect the combo to many computer systems.

The program is capable of connecting to the **abiocardserver** program over a network. This mode allows you to inspect and control the AbioCard remotely, thus from another computer.

A nice feature of the program is the ability to work with AbioRTC and AbioWire devices. You can use the program to get and set the date and time of the real-time clock chip.

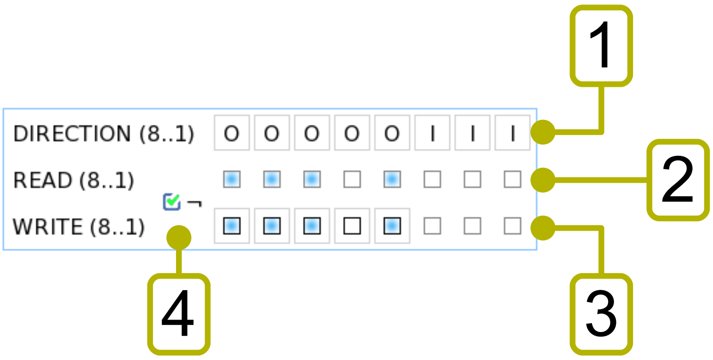
User Interface

The Interface Panel



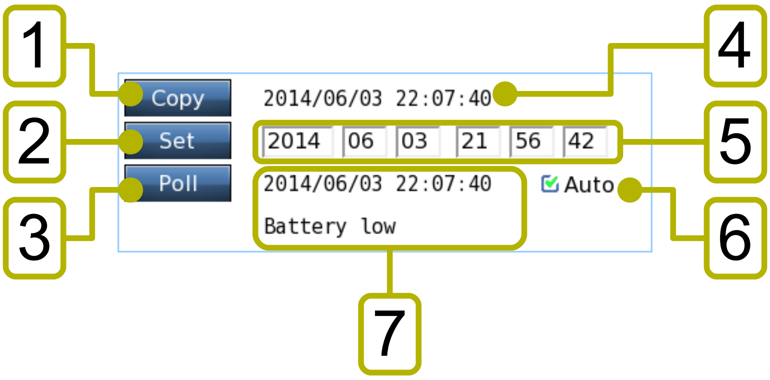
Mark	Description
1	Click the left arrow and right arrow to cycle through the available interfaces. The selected interface is shown between the arrows.
2	For i2c-dev I/O, you've to enter the device path here.
3	For network I/O, you've to enter the host here. The application accepts three representations: ▪ An IPv4 address. ▪ The word **localhost**. It's interpreted as IPv4 address 127.0.0.1. ▪ A domain name. Upon connection, the application will perform a DNS look up to determine the corresponding IPv4 address.
4	For network I/O, you've to enter the port number here.
5	For use with an AxiCat, you've to enter the serial path here.
6	Click the PWM button to show the panel for the LED driver of model A.
7	Click the PWM2 button to show the panel for the LED driver of model B.
8	Click the Connect button to connect with the AbioCard.
9	Click the Disconnect button to disconnect from the AbioCard.
10	Status information is displayed here.

The I/O Expander Panel



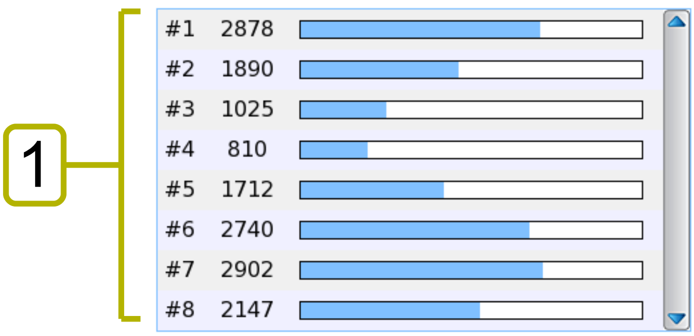
Mark	Description
1	Click the buttons to toggle the direction of the I/O channel.
2	State of the I/O lines.
3	For I/O channels with output direction, click to toggle the output state.
4	Inverse logic checkbox. This checkbox is a visual-only control. Toggling it does not change the state of the I/O expander chip.

The Real-time Clock Panel



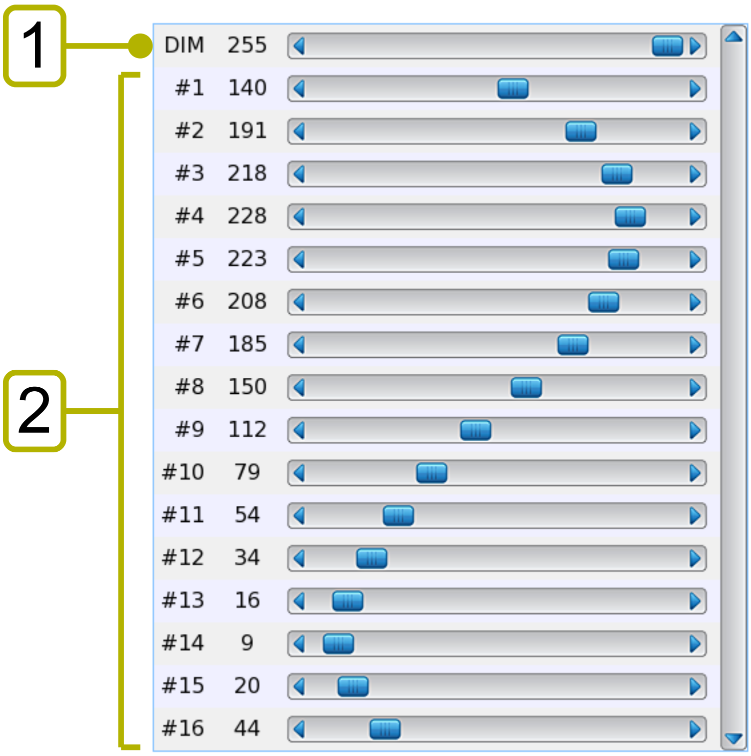
Mark	Description
1	Click the Copy button to copy the system time to the edit fields for data and time. The system time is displayed next to the Copy button.
2	Click the Set button to write the date and time in the edit fields to the AbioCard.
3	Click the Poll button to force a clock read command with the AbioCard. This button is useful when the Auto-poll checkbox is unchecked.
4	The current system time.
5	These edit fields enable you to enter a date and time which you can set in the AbioCard device using the Set button.
6	The Auto-poll checkbox let you decide whether the application automatically polls the real-time clock.
7	The information most recently read from the real-time clock.

The Analog-to-Digital Converter Panel



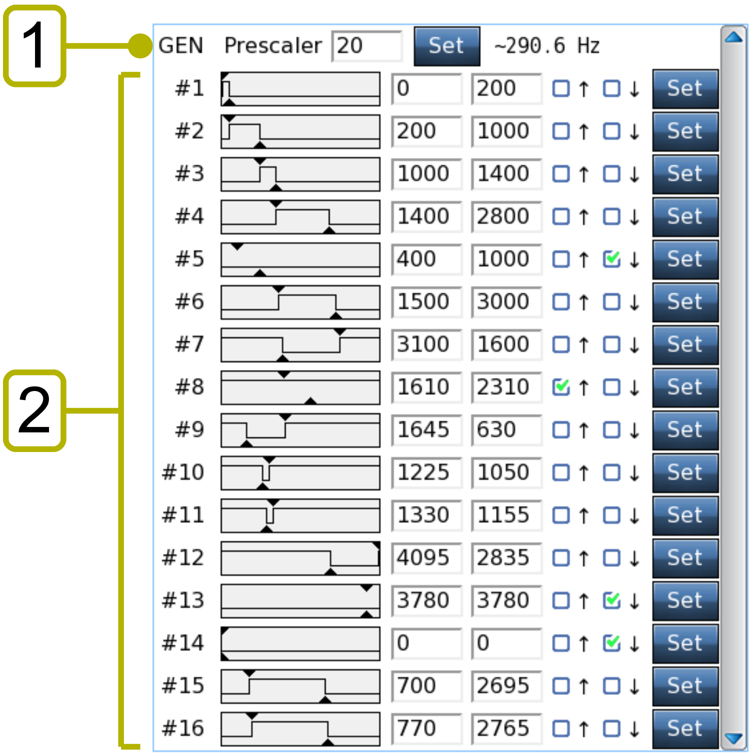
Mark	Description
1	The state of the analog inputs.

The LED Driver Panel for model A

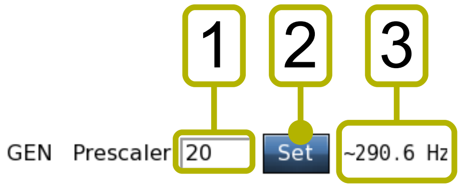


Mark	Description
1	The state of the PWMGRP register. Slide the scrollbar to adjust the value.
2	The state of registers PWM0 to PWM15. Slide a scrollbar to adjust the value.

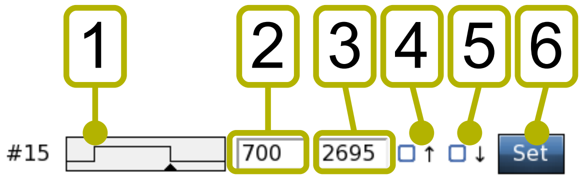
The LED Driver Panel for model B



Mark	Description
1	General settings of the LED driver.
2	The state of each output channel.



Mark	Description
1	The prescaler value.
2	Click the Set button to write the prescaler value to the LED driver.
3	The calculated PWM frequency based on the prescaler value.



Mark	Description
1	Expected PWM wave form of the output signal. You can click and drag the top triangle and bottom triangle to change the values of ON time and OFF time.
2	The value of the ON time. Click the Set button to apply.
3	The value of the OFF time. Click the Set button to apply.
4	The state of the Always ON flag. Click the Set button to apply.
5	The state of the Always OFF flag. Click the Set button to apply.
6	Click the Set button to write the data specified in 2, 3, 4 and 5 to the LED driver.

Command Line

Not applicable. The program ignores the command line.

Module rpidetect

A Raspberry Pi computer is built around the BCM2835 or BCM2836 application processor. The **rpidetect** module is designed to detect a Raspberry Pi computer.

All programs that communicate with the AbioCard using direct I/O access the application processor's hardware registers directly from user-mode using memory-mapped I/O. Running these programs on a system other than a Raspberry Pi computer will lead to unpredictable results unless they're aware of the presence or non-presence of the expected hardware. To guarantee such problems won't occur, the programs incorporate the **rpidetect** module. They will first detect the Raspberry Pi hardware before they make any attempt to access the AbioCard.

API

Each function in the API is briefly explained. Refer to the source code for more details.

```
VOID  rpidetect (RPIDETECT_IO *io)
```

Runs the detection procedure.

If field io->chip is non-zero, the function has successfully detected a Raspberry Pi computer and the field tells which application processor is present.

Source

Filename	Description
`rpidetect.c`	Implementation of the module.
`rpidetect.h`	Public header of the module.

Module abiocard

The **abiocard** module offers an API in C for communicating with the AbioCard from your own program.

This module can also be used for driving the real-time clock on AbioRTC and AbioWire.

Hardware Configuration

The chips on the AbioCard offer many features and configurations. To keep the software simple, the **abiocard** module offers a broad subset of the AbioCard's capabilities through its API. The programs **abiocardserver** and **abiocardgui** support the same subset.

Chip	Supported subset
Real-time clock	▪ Power-up detection during polling. ▪ Low battery detection during polling. ▪ Current time and date function, 24-hour mode only, weekday not used.
8-bit I/O expander	▪ Not configurable.
Analog-to-digital converter	▪ Unipolar: sampling values are 12-bit unsigned (0..4095). ▪ Single-ended use of the analog inputs. ▪ All 8 analog inputs are converted in one command. ▪ Using internal clock. ▪ Using internal voltage reference (4.096V).

Model A
LED driver
	▪ All LED outputs programmable.
	▪ All LED groups under dimming control, no blinking.
	▪ Software handling of dimming value:
	    ▪ When GRPPWM is 0..254, all LED group are set to mode 3.
	    ▪ When GRPPWM is 255, all LED group are set to mode 2.
	▪ INVRT=1: Output logic state inverted.
	▪ OUTDRV=1: Totem-pole structure.
	▪ DMBLNK=0: Group control is dimming.
	▪ OCH=0: Outputs change on I2C STOP command.
	▪ OUTNE[1..0]=10b: When $\overline{\text{OE}}$ is high, LED outputs are high-impedance. Note that $\overline{\text{OE}}$ is hardwired to ground.

Model B LED driver	▪ All LED outputs programmable. ▪ EXTCLK=0: Use the internal clock of 25 MHz. ▪ INVRT=0: Output logic state not inverted. ▪ OUTDRV=1: Totem-pole structure. ▪ OCH=0: Outputs change on I2C STOP command. ▪ OUTNE[1..0]=10b: When $\overline{\text{OE}}$ is high, LED outputs are high-impedance. Note that $\overline{\text{OE}}$ is hardwired to ground.

API

The API support the hardware configuration described in the previous chapter.

Each function in the API is briefly explained. Refer to the source code for more details.

```
ABIOCARD_HANDLE  abiocard_init (ABIOCARD_INIT_IO *io)
```

Initializes an instance of the AbioCard driver. This function performs the following tasks:

- It creates a context for the AbioCard driver.
- It probes for the presence of the various chips on the AbioCard. The software is indiscriminate of the model of AbioCard. At least one chip must be present, else initialization fails.
- It initializes the analog-to-digital converter chip, if present.
- It initializes the LED driver chip for AbioCard model A, if present.
- It initializes the LED driver chip for AbioCard model B, if present.

When the function returns a non-zero value, the initialization was successful and the other functions can be called safely with the returned handle.

When the function returns zero, there was an error. The **`io->err`** field will contain the error code. Note that it's allowed to call **`abiocard_deinit`** with a handle value of zero.

```
VOID  abiocard_deinit (ABIOCARD_HANDLE handle)
```

Deinitializes the instance of the AbioCard driver associated with the given handle. A program must call this function when it's done using the module.

If **`handle`** is zero, the function does nothing.

```
FLAG  abiocard_is_detached (ABIOCARD_HANDLE handle)
```

The AbioCard driver mark the device as detached when it encounters an unrecoverable error. This function returns the detached state.

By calling this function regularly, software can poll for the detached state. Software usually stops using and deinitializes the AbioCard driver when it's marked as detached.

```
FLAG  abiocard_rtc_poll
(
    ABIOCARD_HANDLE handle,
    ABIOCARD_RTC_POLL_INFO *info
)
```

Polls the real-time clock. The results are written to the buffer pointed to by **`info`**.

Returns one when successful, zero when something went wrong.

```
FLAG  abiocard_rtc_set_time
(
    ABIOCARD_HANDLE handle,
    ABIOCARD_RTC_TIME *time
)
```

Sets the given date and time in the real-time clock.

Returns one when successful, zero when something went wrong.

```
FLAG  abiocard_ioexp_write (ABIOCARD_HANDLE handle, U8 word)
```

Writes the given 8-bit value to the I/O pins of the I/O expander chip.

Returns one when successful, zero when something went wrong.

```
FLAG  abiocard_ioexp_read (ABIOCARD_HANDLE handle, U8 *word)
```

Reads the I/O pins of the I/O expander chip and writes the resulting 8-bit value at the address pointed to by **`word`**.

Returns one when successful, zero when something went wrong.

```
FLAG  abiocard_adc_convert
(
    ABIOCARD_HANDLE handle,
    ABIOCARD_ADC_CNV_DATA *buf
)
```

Converts all analog inputs and stores the resulting values in the buffer pointed to by **`buf`**.

Returns one when successful, zero when something went wrong.

```
FLAG  abiocard_pwm_write_range
(
    ABIOCARD_HANDLE handle,
    U8 *buf, U8 start, U8 cnt
)
```

Writes a range of values to the LED driver chip on an AbioCard model A. The values are written to indexes numbered 0 to 16. Parameter **`start`** is the first index, parameter **`cnt`** the number of values to write. Parameter **`buf`** points to the source buffer.

Indexes 0 to 15 correspond with registers PWM0 to PWM15, index 16 with register GRPPWM in the LED driver chip.

Returns one when successful, zero when something went wrong.

```
FLAG  abiocard_pwm_read_range
(
    ABIOCARD_HANDLE handle,
    U8 *buf, U8 start, U8 cnt
)
```

Reads a range of values from the LED driver chip on an AbioCard model A. The values are read from indexes numbered 0 to 16. See function **abiocard_pwm_write_range** for a description of the meaning of the indexes.

Returns one when successful, zero when something went wrong.

```
FLAG  abiocard_pwm2_write_range
(
    ABIOCARD_HANDLE handle,
    ABIOCARD_PWM2_CH *buf, U8 start, U8 cnt
)
```

Writes the PWM values for one or more channels to the LED driver chip on an AbioCard model B. The values are written to indexes numbered 0 to 15.

Returns one when successful, zero when something went wrong.

```
FLAG  abiocard_pwm2_read_range
(
    ABIOCARD_HANDLE handle,
    ABIOCARD_PWM2_CH *buf, U8 start, U8 cnt
)
```

Reads the PWM values for one or more channels from the LED driver chip on an AbioCard model B. The values are read from indexes numbered 0 to 15.

Returns one when successful, zero when something went wrong.

```
FLAG  abiocard_pwm2_write_prescaler (ABIOCARD_HANDLE handle, U8 val)
```

Writes to the prescaler register of the LED driver chip on an AbioCard model B.

Returns one when successful, zero when something went wrong.

```
FLAG  abiocard_pwm2_read_prescaler (ABIOCARD_HANDLE handle, U8 *val)
```

Reads from the prescaler register of the LED driver chip on an AbioCard model B.

Returns one when successful, zero when something went wrong.

Distribution Packages

Package abiocard

The **abiocard** package contains the software that is essential for working with the AbioCard.

The package includes source text that you can use to develop your own software for the AbioCard in Linux and Windows.

Package abiocardgui

The **abiocardgui** package is supplied for various operating systems.

Installation

Package abiocard

This section assumes you've connected the AbioCard to the GPIO header of a Raspberry Pi computer.

Unpack the **abiocard** package in a local directory in your home directory on your Raspberry Pi computer.

Run the **install_abiocard_rpi.sh** script in the context of your user account to install the **abiocard** group of programs in Linux.

Be sure to run the installation script from the command line rather than the file manager. The script will **sudo** and as such the system may ask for the root password.

The installation script will add three lines to the cron table of the root user:

- Run the **abiocardtime** program at reboot.
- Run the **abiocardtime** program daily.
- Start the **abiocardserver** program at reboot (port 5678, timeout 20 seconds).

The installation script will install the programs in directory **/opt/abiocard**.

To set the date and time of the real-time clock and your operating system, run the following command with the correct date and time set with the **-s** parameter:

```
$ /opt/abiocard/abiocardtime -u -s "2014-06-10 14:40:55"
```

Package abiocardgui

Linux

Unpack the **abiocardgui** package in a local directory in your home directory. Be sure you pick the distribution that corresponds with your operating system.

Run the **install.sh** script in the context of your user account to install the **abiocardgui** program in Linux.

Be sure to run the installation script from the command line rather than the file manager. The script runs **sudo** and as such the system may ask for the root password.

The installation script will install the files in directory **/opt/abiocardgui**.

The installation script will add a icon on your desktop by placing a desktop file in the Desktop directory in your home directory. This feature works only if your window manager is compliant with the Desktop Entry Specification by the **freedesktop.org** organization.

Windows

Unpack the **abiocardgui** package for Win32 in a local directory on your system.

Execute **abiocardgui.exe** to run the application. You can create a shortcut to the executable file on your desktop.

Software License

Package abiocard

The license is stated in the source text files.

Program abiocardgui

The computer program **abiocardgui** is free of charge ("freeware").

It's allowed to copy or distribute the software providing that you do so with the distribution in its entirety as described in chapter Distribution Packages. It's forbidden to change the software or any other files that are part of the distribution.

It's forbidden to sell, rent, or profit from the distribution in its entirety or the software or any other files that are part of the distribution.

It's allowed to spread the distribution in a packaging format different from the packaging format provided by Axiris.

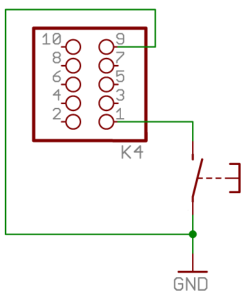
7 Application Examples

8-bit I/O Expander

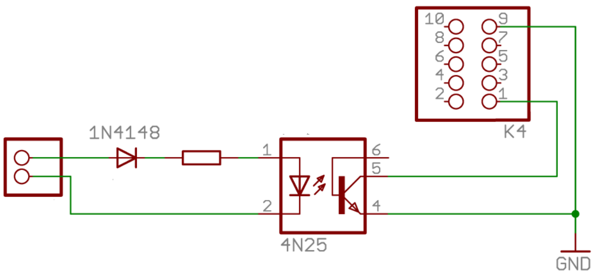
Basic Input

This is a minimalistic circuit for using an input. When the button is unpressed, the input is internally pulled to 5 V and is read as HIGH. When the button is pressed, the input is pulled to ground and is read as LOW.

Software must set the I/O pin to HIGH to use it as an input.



Optically Isolated Input

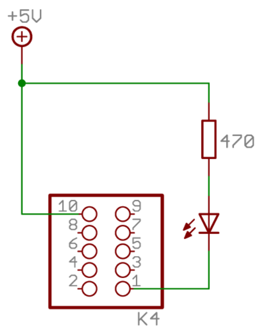


In this example, the input is optically isolated from the control circuit.

Software must set the I/O pin to HIGH to use it as an input.

Basic LED Drive Output

This example circuit shows an output driving a LED. When the output is LOW, the LED will light up. When the output is HIGH, the LED is off.



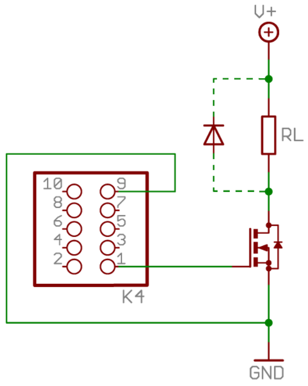
IMPORTANT!
▪ You must choose the resistor value depending on the type of LED and the expected light intensity. ▪ The LED mustn't draw more than 25 mA. If multiple outputs are connected to LEDs as shown in the picture, than the total current mustn't exceed 100 mA. See the datasheet for more information.

Output with MOSFET Transistor

This example circuit shows how to switch a load using an enhancement-mode N-channel MOSFET.

It's important to use a logic-level MOSFET that switches on reliably at 5 V gate voltage. Example MOSFETs include 2N7000, IRL520, IRFD220, BTS141.

The maximum load current and load voltage depend on the type of MOSFET. For inductive loads, it's recommended to add a clamp diode as depicted.

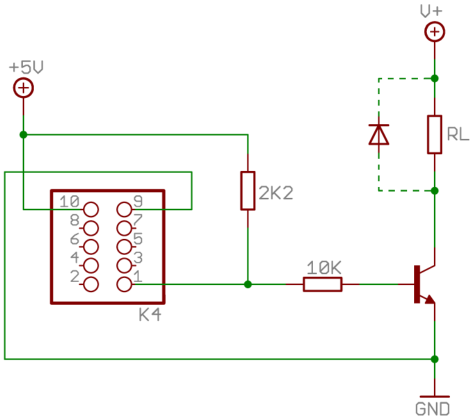


Output with Bipolar Transistor

This example circuit shows how to switch a load using an NPN bipolar transistor. You can replace the NPN transistor with a NPN Darlington transistor to increase the current amplification.

The maximum load current and load voltage depend on the type of transistor. For inductive loads, it's recommended to add a clamp diode as depicted.

The maximum current sourced by the I/O expander chip is 100 µA. It's recommended to add an additional pull-up resistor to increase the base current through the transistor. The pull-up resister also guarantees the I/O expander correctly reads back a HIGH level when software sets the output HIGH.

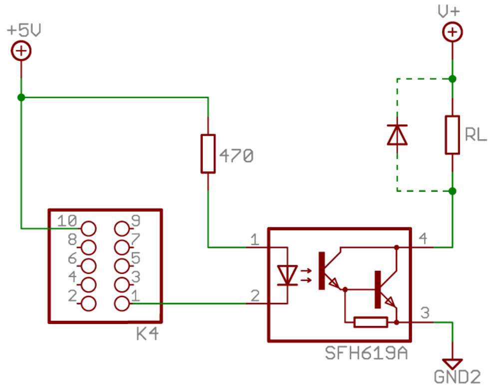


The set-up with the MOSFET is recommended over this example circuit.

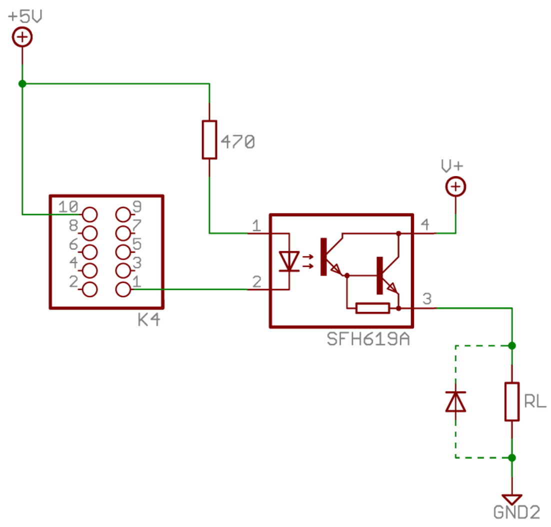
Optically Isolated Output (low side switch)

This example shows an optically isolated output (low side switch).

The optocoupler used in this example is able to switch 125 mA maximum at 300 V maximum.

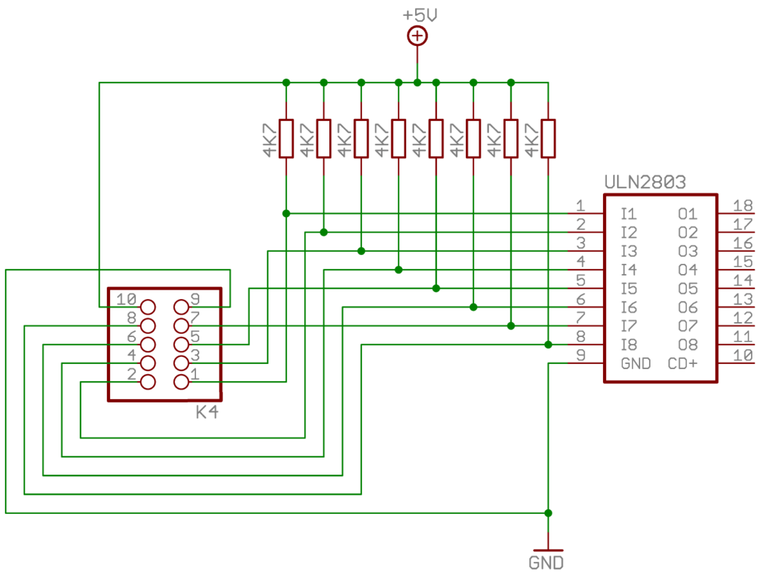


Optically Isolated Output (high side switch)



This example shows an optically isolated output (high side switch).

Outputs with ULN2803 Driver



In this example, all eight output are connected to a ULN2803 driver.

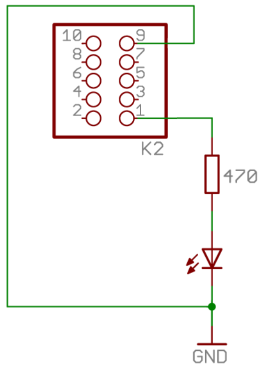
The I/O expander chip can only source 100 µA per output. The pull-up resistors are required to reliably drive the inputs on the ULN2803.

LED driver

Basic PWM Output for Driving a LED

This example circuit shows how to control the intensity of a LED using an output of the LED driver.

The maximum LED current mustn't exceed 10 mA.

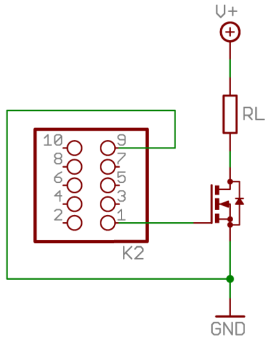


PWM Output with MOSFET Transistor

This example circuit shows how to switch a load using an enhancement-mode N-channel MOSFET.

It's important to use a logic-level MOSFET that switches on reliably at 5 V gate voltage. Example MOSFETs include 2N7000, IRL520, IRFD220, BTS141.

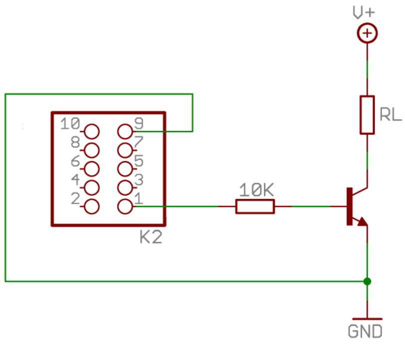
The maximum load current and load voltage depend on the type of MOSFET. It's not recommended to connect inductive loads.



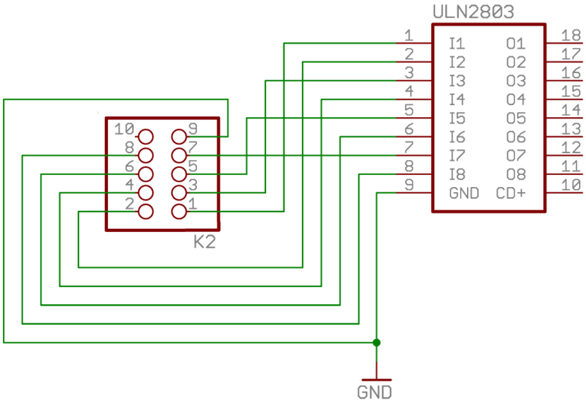
PWM Output with Bipolar Transistor

This example circuit shows how to control the intensity of a LED using an NPN bipolar transistor.

The maximum load current depends on the type of transistor.



PWM Outputs with ULN2803 Driver



In this example, all eight outputs are connected to a ULN2803 driver.

Since the LED driver chip can source enough current to drive the ULN2803, pull-up resistors are not required.

8 Legal Information

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9 Contact Information

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