Product Features & Specification

Electrical Interface

- 200,000 gate user-configurable FPGA (Xilinx XC6SXLX9).
- On-board SPI flash for stand-alone use or rapid FPGA configuration.
- Footprint compatible with the Raspberry Pi Rev1, Rev2, Model A & Model B.
- Arduino™ Shield interface supports both 3.3V & 5V Arduino™ shields.
- RIO(P1) – 26 pin (2x13) Samtec ESW series socket provides an interface to the Raspberry Pi's P1 3.3v GPIO. All 17 I/O pins are connected plus 5v power & GND.
- GPIO1 – 24 x 3.3v general-purpose, single-ended or differential programmable I/O port on a 26-pin (2x13) Samtec TSW series header. Includes connections for 3.3v power & GND.
- GPIO2 – 16 x open-collector programmable output port on a 39-pin (3x13) Samtec TSW series header. Includes 8 high-current (2A) open-drain drivers and 8 low-current (100mA) open-collector drivers. The pin-out is designed to interface directly to up to 12 radio-control style 'hobby' servos. Includes connections for GPIO2 power (normally +5v) & GND.
- GPIO3 – 16 x 5v (or 3.3v) general-purpose programmable I/O port on a 26-pin (2x13) Samtec TSW series header. The pin-out is directly compatible with a number of simple 2-line LCD or vacuum florescent display modules. This port can be optionally configured as 3.3v I/O to extend the I/O provided by GPIO1. Includes connections for GPIO3 power (5v or 3.3v) & GND.
- 1 x RS232 serial port (TXD, RXD, RTS & CTS) or 2 x RS232 serial ports (TXD & RXD only) on a 10-pin (2x5) Samtec TSW series header. The pin-out is designed to mate to an IDC 9-way male 'D' connector to provide a pin-out that matches a standard 'DTE' RS232 serial port connector.
- 8-channel 200ksps ADC (Texas Instruments ADC128S022) plus 4-channel DAC (Microchip MCP4728) on a 16-pin (2x8) Samtec ESW series socket. Includes connections for 3.3v power, reference out, reference in and GND.
- 4 general purpose push-button switches.
- 8 general purpose green LEDs.
- 3-axis magnetometer (InvenSense MPU-9150).
- 3-axis accelerometer (InvenSense MPU-9150).
- 3-axis gyroscope (InvenSense MPU-9150)..
- User access to the 4Mbit SPI flash FPGA configuration memory provides over free-to-use 512kbit of general-purpose non-volatile storage.
- 25MHz local oscillator.
- Integrated power switch to support intelligent control of the power supply to the Raspberry Pi.
- 2.1mm DC 'Jack' power connector for unregulated 6.5v-15v external power supply.
- Optional location for a 6-pin JTAG programming & debug connector (not fitted or supplied). Pin-compatible with a Digilent JTAG USB cable.

Power:

- Requires external 6.5v – 15v DC 20W power supply which can also be used to power the Raspberry Pi via the on board 5v regulator or it can be powered from the 5V supply on the Raspberry Pi.
- Power consumption: < 0.5W (typ) at 6.5V.
- On-board 5V, 3A (4A peak) 90% efficient switch-mode power supply supports input supply from 6.5v to 15v.
- Provides regulated 5V supply to the Raspberry Pi.
- Reverse polarity protection.
- On-board 3.3v switching regulator
- On-board 1.2v linear regulator.

Mechanical:

- Board dimensions: 56mm x 123mm x 1.6mm thick.
- Top side component height: 14mm
- Bottom side component height: 3mm
- Weight: 48g
- Fixing: 2 x 2.5mm (clearance) M2.5 fixing points, matching the hole pattern on the Raspberry Pi rev 2.

Product Description

The PiXi (2.0) is designed to operate with the Raspberry Pi single-board computer to extend its I/O capability, provide a basis for and encourage an introduction to digital logic design using FPGA technology, add a few frequently called-for & interesting functions and provide a platform that could be used for product development.

The PiXi (2.0) plugs directly onto the Raspberry Pi using the Raspberry Pi's P1 connector and can be secured in place using readily available M2.5 screws & 19mm pillars.

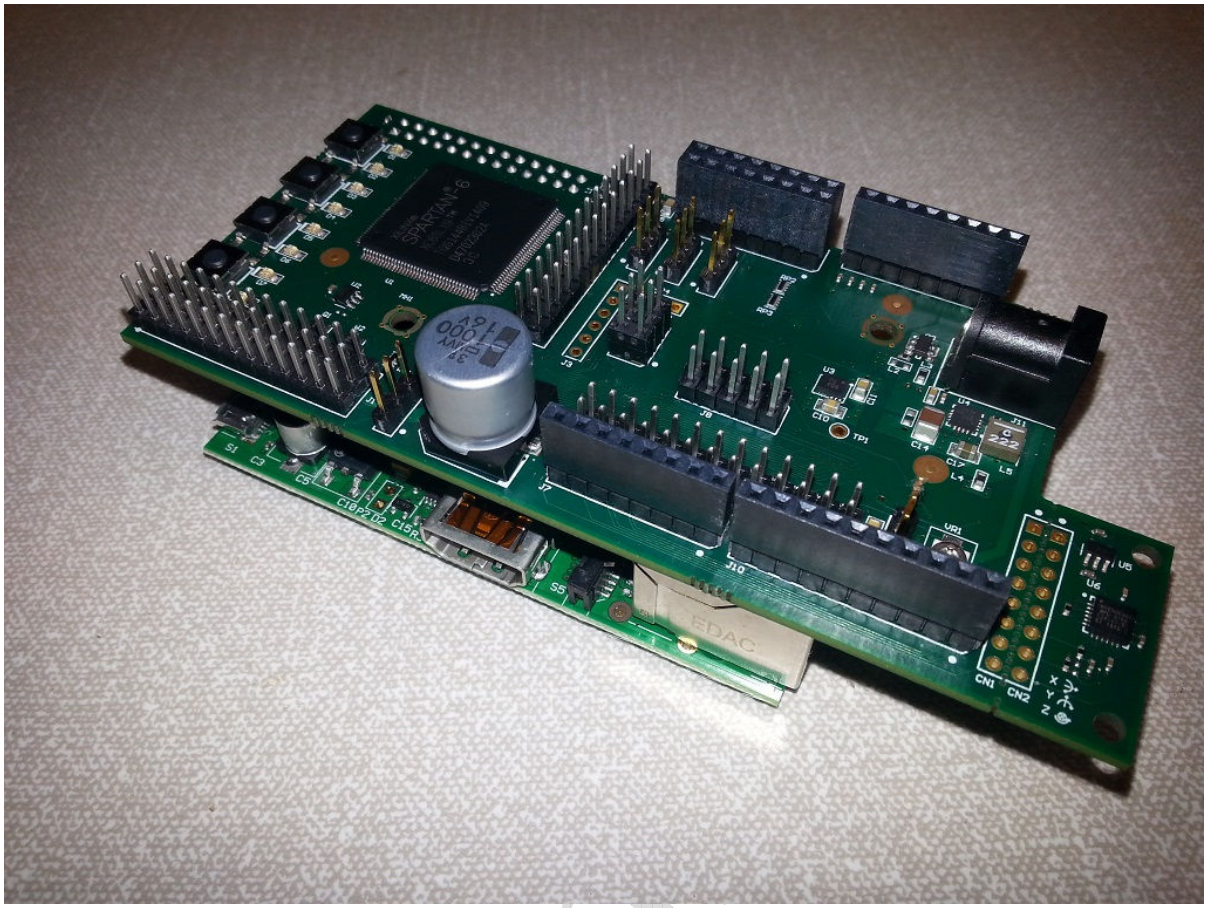

Figure 1: The original prototype PiXi (2.0) secured to a Raspberry Pi Model B

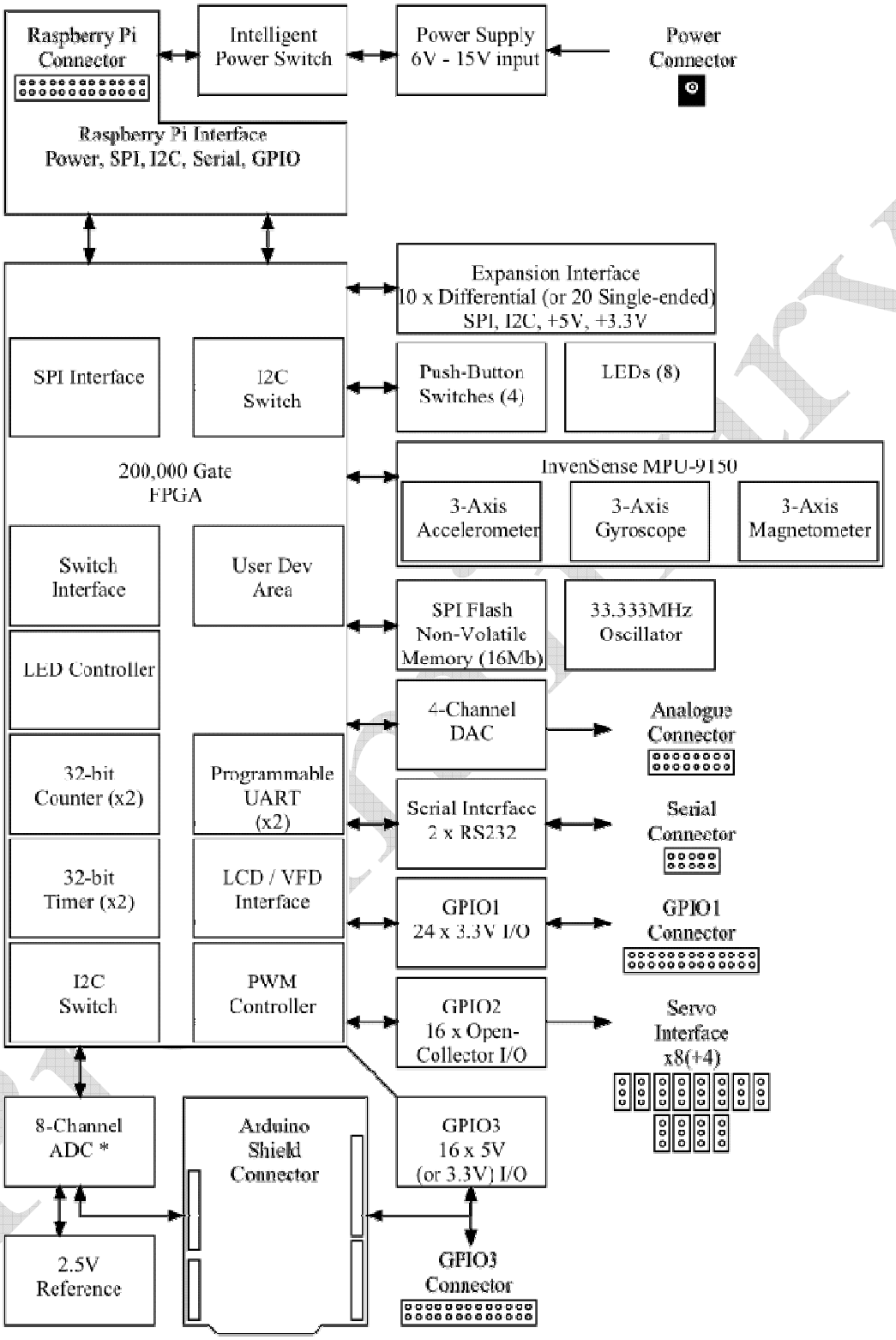

Figure 2: PiXi (2.0) Functional Diagram

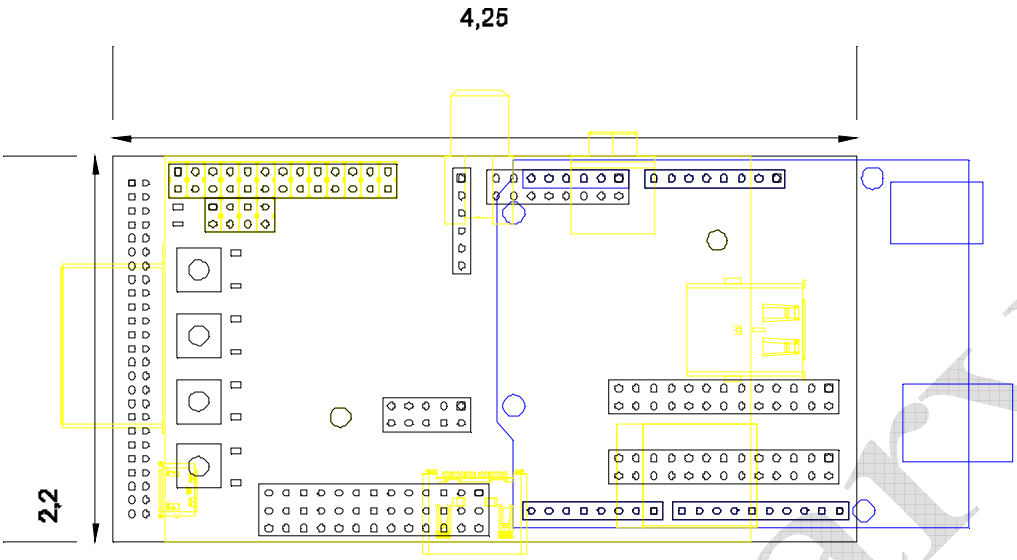

Figure 3: Physical Dimensions & Interface Drawing

Interface Specification

GPIO1

Board reference:	J3
Connector:	26-pin (2x13) 0.1" Samtec TSW series header
I/O standard:	24 x 5mA LVCMOS (3.3V) Optional: Any 3.3V "IOSTANDARD" supported by the FPGA (requires FPGA development)
Power output:	3.3V (maximum 500mA load)
Datarate:	100 Mbps.
Driver / interface:	FPGA direct.

Pin	Function	Pin	Function
1	+5V (<500mA)	2	GND
3	GPIO1-0	4	GPIO1-1
5	GPIO1-2	6	GPIO1-3
7	GPIO1-4	8	GPIO1-5
9	GPIO1-6	10	GPIO1-7
11	GPIO1-8	12	GPIO1-9
13	GPIO1-10	14	GPIO1-11
15	GPIO1-12	16	GPIO1-13
17	GPIO1-14	18	GPIO1-15
19	GPIO1-16	20	GPIO1-17
21	GPIO1-18	22	GPIO1-19
23	GPIO1-20	24	GPIO1-21
25	GPIO1-22	26	GPIO1-23

Table 1 GPIO1 connector pin-out

The I/O standard for each GPIO pin defaults to 3.3V CMOS, with an I/O drive current of 5mA. The I/O is directly connected to the FPGA so the I/O can be changed to any 3.3V standard supported by the FPGA by changing the FPGA configuration.

Each pin may be individually configured as an input, output or special function. See the PiXi (2.0) FPGA Reference Manual for details on how to configure the I/O.

The default FPGA configuration provides access to GPIO1 input & output functions over the SPI interfaces on the Raspberry Pi's P1 connector.

GPIO2

Board reference:	J4
Connector:	39-pin (3x13) Samtec TSW series header

I/O standard: 8 x open-collector (100mA) plus 8 x open-drain (2A)
Power output: 4.5V - 5V (maximum 2.5A load) or VIN (-0.5V) (maximum 5A load). Note there is a schottky diode in line with the power feed to the connector which is why the output voltage is typically around 0.5v lower than the source. The diode is there to allow the user to connect an external supply to GPIO2_V+.
Datarate: 2 Mbps.
Driver / interface:

Pin	Function	Pin	Function	Pin	Function
1	GPIO2-0	2	GPIO2_V+	3	GND
4	GPIO2-1	5	GPIO2_V+	6	GND
7	GPIO2-2	8	GPIO2_V+	9	GND
10	GPIO2-3	11	GPIO2_V+	12	GND
13	GPIO2-4	14	GPIO2_V+	15	GND
14	GPIO2-5	17	GPIO2_V+	18	GND
19	GPIO2-6	20	GPIO2_V+	21	GND
22	GPIO2-7	23	GPIO2_V+	24	GND
25	GPIO2-8	26	GPIO2_V+	27	GPIO2-9
28	GPIO2-10	29	GPIO2_V+	30	GPIO2-11
31	GPIO2-12	32	GPIO2_V+	33	GPIO2-13
34	GPIO2-14	35	GPIO2_V+	36	GPIO2-15
37	GND	38	GPIO2_V+	39	GND

Table 2 GPIO2 connector pin-out

GPIO2(0) – GPIO2(7) provides a low-current (100mA) open-collector output (pull to GND) with a 1k internal pull-up to GPIO2_V+.

GPIO2(8) – GPIO2(15) provides a high-current (2A) open-drain output drive (pull to GND) with no internal pull-up.

The locations of power, low-current drive & high-current drive are designed to offer a pin-out that is compatible with a typical 3-pin radio-control style or 'hobby' servo motor connector. The GPIO2_V+ pin provides power to the servo while the low-current drive provides the PWM servo position control signal. Please note that while this pin-out matches the majority of radio-control style servos, some servos have a different pin-out that typically swaps the supply & ground connections so it's important to check for compatibility before connecting the servo connector.

GPIO3

Board reference: J5
Connector: 26-pin (2x13) Samtec TSW series header
I/O standard: 16 x 5mA CMOS (5V), 5mA LVCMOS (3.3V) or open-collector
Power output: 4.5V - 5V (maximum 2.5A load) or VIN (-0.5V) (maximum 5A load). Note there is a schottky diode in line with the power feed to the connector which is why the output voltage is typically around 0.5v lower than the source. The diode is there to allow the user to connect an external supply to GPIO2_V+.
Datarate: 60 Mbps push-pull or 2 Mbps open-collector
Driver / interface: Texas Instruments TXS0108.
Other I/O: VO – 1k potentiometer output for controlling the contrast on a small LCD display module.
I2C – 3.3V I2C interface direct from the FPGA. Includes a 1k pull-up on SDA & SCL.

Pin	Function	Pin	Function
1	GPIO3_V+	2	GND
3	GPIO3-9	4	VO
5	GPIO3-10	6	GPIO3-11
7	GPIO3-0	8	GPIO3-1
9	GPIO3-2	10	GPIO3-3
11	GPIO3-4	12	GPIO3-5
13	GPIO3-6	14	GPIO3-7
15	N/C	16	N/C
17	N/C	18	N/C
19	I2C-SCL (3.3v)	20	I2C-SDA (3.3v)
21	GPIO3-12	22	GPIO3-13
23	GPIO3-14	24	GPIO3-15
25	GPIO3-8	26	GND

Table 3 GPIO3 connector pin-out

Pins 1 – 14 are designed to be directly compatible with a 14-pin connector found on some two-line or four-line LCD & vacuum florescent display (VFD) modules. If this interface is required then a 26 pin IDC socket may be used with the first 14 (or 16) signal wires separated to allow them to fit a 14 (or 16) pin IDC socket at the opposite end of the cable.

Important Note: The pin-out of GPIO3 is designed to support a direct connection to a LCD or vacuum fluorescent display fitted with a 14 (or 16) pin IDC header or socket. The header / socket on the LCD module must be fitted to the underside of the display board. This has been done deliberately since there is usually very little head-room for a removable connector on the top surface of the display board if it is mounted directly behind a panel or window. Please check compatibility before connecting the LCD or VFD.

Serial

Board reference: J8
Connector: 10-pin (2x13) Samtec TSW series header
I/O standard: EIA/TIA-232-F (2 x RX + 2 x TX)
Power output: No power available.
Datarate: up to 250kbps
Driver / interface: Exar SP3232EB

Pin	Function	Pin	Function
1	N/C	2	N/C
3	RX0	4	RTS0 / TX1
5	TX0	6	CTS0 / RX1
7	N/C	8	N/C
9	GND	10	N/C

Table 4 Serial connector pin-out

Analogue

Board reference: J7
Connector: 16-pin (2x8) Samtec BCS series socket
I/O standard: DAC output: 0-2.048V or 0-3.3V ADC input: 0-2.5V or 0-REF_IN
Power output: 3.3V (maximum 50mA load)
Datarate (ADC): up to 100k samples per second
Driver / interface: ADC: Microchip MPC3208, DAC: MCP4728, Reference: MCP1525

Pin	Function	Pin	Function
1	DAC_CH0	2	ADC_CH0 *
3	DAC_CH1	4	ADC_CH1 *
5	DAC_CH2	6	ADC_CH2 *
7	DAC_CH3	8	ADC_CH3 *
9	REF_OUT	10	ADC_CH4 *
11	REF_IN	12	ADC_CH6 *
13	A_V+ (3.3V)	14	ADC_CH6
15	GND	16	ADC_CH7

Table 5 Analogue connector pin-out

* ADC_CH0 to CH5 form part of the Arduino™ shield interface

The Analogue interface connector is designed to form part of the ArduinoTM shield interface, which is why it is designed in as a socket. A wire link should be inserted between pin9 and pin 11 to select the reference.

Expansion Interface

Board reference: J?
Connector: 50-pin (2x25) 2mm hole pattern compatible with Samtec BCS series header socket
I/O standard: LVDS (3.3V), LVCMOS (3.3V)
Power output: 3.3V (maximum 500mA load), 5V (maximum 1A load)
Datarate: up to 100Mbps
Driver / interface: FPGA Direct.

Arduino™ Shield Interface

The PiXi (2.0) provides an Arduino™ compatible 'Shield' interface that supports a number of 3.3v or 5v Arduino™ shields which can be used & controlled with the Raspberry Pi using the PiXi (2.0) to provide the physical interface and I/O functions typically found on the Arduino™ series of products.

On-Board Functions

FPGA

Board reference: U65
Part number: Xilinx XC6SLX9-FTG256C
Datasheet: Available at www.xilinx.com

The FPGA is pre-configured on initial power-up using the configuration stored in the SPI flash to provide a number of general-purpose functions. However the user can chose to load one of several example configurations or chose to develop the FPGA themselves, either from scratch or from one of the several example projects supplied.

FPGA development requires the use of the Xilinx Webpack™ tools which may be downloaded free of charge from the Xilinx website at www.xilinx.com.

All software, example projects, VHDL & Verilog source code is available from the Astro-Designs project on GitHub https://github.com/astro-designs.

Users are encouraged to share their designs through the Astro Designs website www.astro-designs.com/community.php.

Astro Designs software, VHDL & Verilog source code is provided free of charge and may be re-distributed and/or modified under the terms of the GNU Lesser General Public License (LGPL) as published by the Free Software Foundation, either version 3 of the License or (at the users option) any later version.

Configurations can be downloaded to the FPGA or SPI flash using either the Raspberry Pi, Xilinx PlatformCable™ USB or the Digilent JTAG USB cable.

Designs can be analysed in-circuit using Xilinx Chipscope™ tools together with the Xilinx PlatformCable™ tools or the Digilent JTAG USB cable.

SPI Flash Non-Volatile Memory

Board reference: U?
Part number: TBD
Datasheet: TBD

The SPI Flash non-volatile memory is provided to support rapid configuration of the FPGA shortly after power-up. However it is big enough to offer the user some non-volatile storage. Once the FPGA is configured, the user can access the SPI flash memory over the Raspberry Pi's SPI port.

ADC

Board reference: U?
Part number: Texas Instruments ADC128S022
Datasheet: Available at www.ti.com
Low pass filter: A single-pole R-C filter is used to reduce noise into the analogue inputs of the ADC.

DAC

Board reference: U?
Part number: Microchip MCP4728
Datasheet: Available at www.microchip.com
Low pass filter: A single-pole R-C filter is used to help minimise any high-frequency noise out of the analogue outputs of the DAC.

Clock Oscillator

Board reference: X1
Part number: TBD
Datasheet: TBD

The clock oscillator is used by the FPGA to drive all clocked processes and generate other clock sources.

RS232 Level Shifter

Board reference: U?
Part number: SP3232EP
Datasheet: Available at www.exar.com

Push-Button Switches

Board reference: S1 - S4
Part number: B3S-1000
Datasheet: Available at www.omron.com

Four user-configurable push-button switches are available. Each switch is connected directly to the FPGA with a 10k pull-down resistor to ground. The status of the switches can be read by accessing a register over the SPI interface.

LED Indicators

Board reference: D1 - D8
Part number: LTST-C190GKT (10mA green LED)
Datasheet: Available at www.lite.com

Eight user-configurable LEDs are available. Each LED is connected direct to the FPGA through a 100ohm resistor and can either be driven from an addressable register or they can be re-assigned during FPGA development.

Intelligent Power Switch

A high-end MOSFET switch is provided to allow the user or the FPGA to disable power to the Raspberry Pi. The general purpose I/O between the Raspberry Pi and the FPGA can be used to intelligently control the power-off sequence to ensure that Raspberry Pi has been properly shut down before removing the power.

9-Axis Motion Sensor

Board reference: U?
Part number: InvenSense MPU-9150
Datasheet: Available for download at www.invensense.com

An InvenSense MPU-9150 is included on the PiXi (2.0) to provide a development platform for applications requiring advanced motion sensing & processing functions. The MPU-9150 is accessible to the Raspberry Pi over the Raspberry Pi's I2C interface.

Full data and application information on the MPU-9150 can be found on the InvenSense website at www.invensense.com.

Power Consumption

	Min	Typ	Max
Test Conditions	All functions in standby /	All functions running	All functions running

	power-down mode, clock running VIN = 6.5V	 VIN = 6.5V	FPGA operating at 100MHz VIN = 6.5V
Power	0.5W	TBD	TBD

Note: Power consumption figures assume the unit is operating n stand-alone mode (no Raspberry Pi connected) with no load on any interface.

Regularity Compliance

Regulatory compliance testing has yet to be conducted on this product at the time that this document was produced. The PiXi (2.0) has been designed to meet CE & FCC regulations applicable to this product. The Product shall also comply with directive 2002/96/EC on waste electrical and electronic equipment (WEEE). Full certification of this product will be conducted in due course before the unit goes on sale.

Applications

- Expanding the I/O capabilities of the Raspberry Pi;
- Low cost teaching aid bringing FPGA technology, VHDL & Verilog design into education;
- Low cost introduction to embedded systems;
- Low cost product development platform;
- University & school technology projects;

Further Reading

Further information on using the PiXi (2.0) can be found in the PiXi (2.0) User Manual and application notes. These documents are available for download from www.astro-designs.com.

Acknowledgements

Raspberry Pi is a trademark of the Raspberry Pi Foundation.

Xilinx,' the Xilinx logo, ISE, Spartan, Webpack & Chipscope are registered trademarks of Xilinx.

Arduino™ is a trademark of Arduino

Astro Designs Ltd. is a private limited company operating in England. Astro Designs Ltd. is not affiliated in any way with Raspberry Pi, Arduino or Xilinx.