PyFly

HAT-ish board for Raspberry Pi Zero and compatible computers with 40 pin connectors

Users Manual

Rev. 0.07
8/11/2018

Overview

The PyFly board is designed for drones, high power rocketry, and RC airplanes. The board will also suit many other applications. Primarily designed for the Raspberry Pi Zero, it will work on any Raspberry Pi with a 40 pin connector. The physical form factor doesn't conform to the Raspberry Pi HAT size, hence the HAT-***ish*** reference.

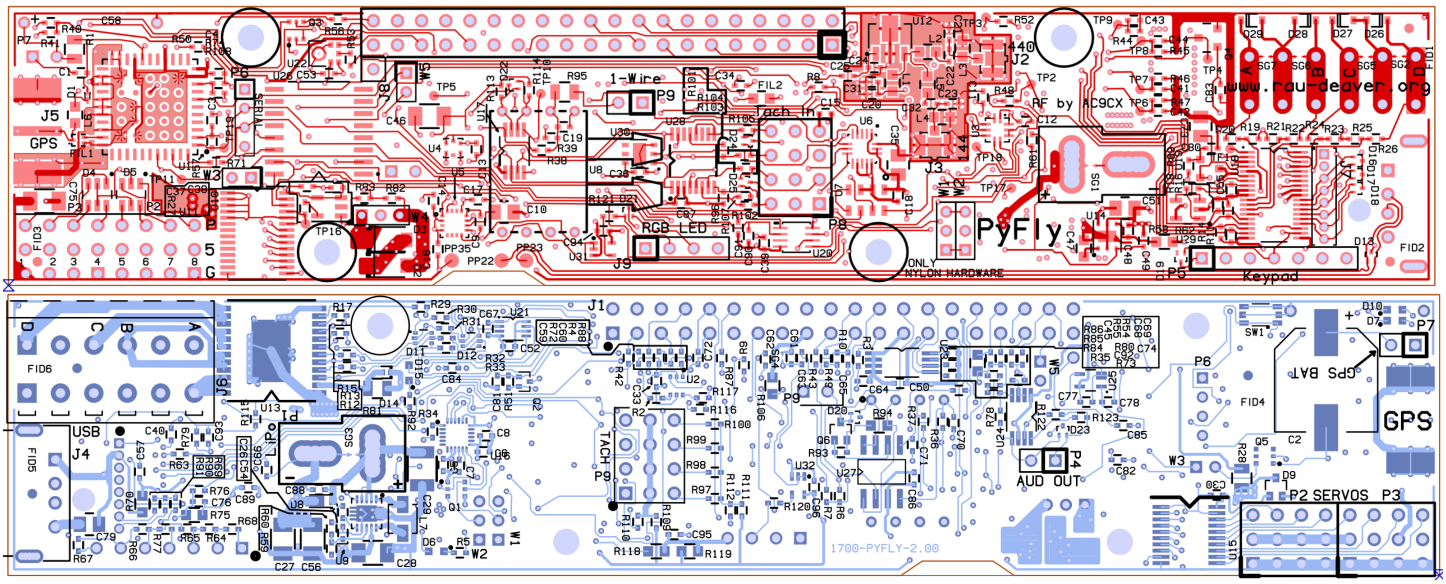


figure 1

Features

- Power: Designed to run on 3 to 12 volts (not 13.8 volt automotive power), it is intended to run on one to three LiPo cells, but any power source will do. A single power supply powers the Raspberry Pi, the HAT board, and its USB device from a 5 volt 2 amp buck-boost switching power supply. The four high current outputs require at least 4.5 volts; i.e. two or three LiPo cells. There is no battery charger.
- Raspberry Pi compatible: The PyFly is intended to connect to the Raspberry Pi Zero so that components of each board face away from the middle. A 40 pin socket could be soldered to the top of the board for use on the Raspberry Pi 3, or any 40 pin Raspberry Pi or compatible.
- RF Transmitter Amplifier and Filter: The board has a dual RF filter and 200mW amplifier. It supports an RF carrier from either GPIO14 or GPIO18. One filter is for the 144MHz HAM band and the other filter is for the 440MHz HAM band. 144MHz transmission can be supported by pifm, nbfm, and rpitx. 440MHz transmission may someday be supported by rpitx, but currently rpitx doesn't seem to work on the Raspberry Pi Zero.
- Servos: Can control up to eight servos. (Standard 6 volt servos will require 2 LiPo cells, higher voltage tolerant servos can use 2 or 3 LiPo cells)
- High Current Outputs: Intended for Rocket upper stage igniters and parachutes, these high current, high side drivers have diagnostics and a redundant enable system to prevent false assertions. Connections use press-to-release terminal blocks.
- Support for headless operation: There is a shutdown button and a shutdown acknowledgment LED for safe headless shutdown. There is also a low battery comparator that can optionally assert the shutdown request.
- Small size: The PyFly has the same width as Raspberry Pi Zero, but it is longer. Dimensions: 29.25mm by 150mm. It is intended to fit a high power rocket 38mm tube coupler, strap on the belly of a quad-copter, or in an RC airplane. Also small enough to be a smart handi-talkie with the addition of a USB software defined receiver. See PDF download on the web site for example application schematics.

- USB redirected: Cannot use the on board Raspberry Pi Zero USB connector in a 32mm width. The USB test points on a Raspberry Pi Zero can be soldered to test points on the HAT board for the USB type A connector and still fit in a narrow fuselage or body tube.
- GPS: The board uses the Skytrac Venus838 module. In binary mode this device can make 50 location updates per second. It has an SMA connector for an external antenna. This allows the use of a helical, omni directional antenna for drones and rockets where there is a lot of roll or pitch. GPS data can be backed up with a super capacitor or an external battery. There is a C library on Github for using the GPS at 50 readings a second. There is also a four pin connector for an external GPS if the board is built without the onboard GPS.
- A/D support: Options for 8, 10, and 12 bit footprint compatible A/D converters. The default build uses the 10 bit TI ADS7957SDBTR A/D converter with 16 channels; 9 channels for internal measurements and diagnostics and 7 external channels. The external A/D connector is a 0.050" pitch connector. Two external channels can be set up for thermistors with no additional components. The last A/D channel is for keypad support. Uses SPI interface.
- Keypad support: A connector for either a standard six-key keypad or a standard 12-key keypad connected through a resistor array to an A/D input. With an external resistor array 26 key keypads are possible.
- High G linear accelerometer: Uses ST Microelectronics H3LIS331D. Uses SPI interface.
- Barometric pressure sensors: There are two options, a Measurement Specialties (TE Connectivity) MS560702BA03-00 as on Altus Metrum's TeleMega that uses the SPI interface. There is also a Raspberry Pi Sensor HAT compatible ST Microelectronics LPS25HBTR on the I2C bus.
- 9 axis inertial and magnetic platform: Uses an Invensense (TDK) MPS-9250 for 3-axis acceleration, 3-axis gyro, and 3-axis magnetometer. Mounted on board centerline, this means there is no parasitic corkscrew acceleration from roll maneuvers. Uses I2C bus.
- Relitive humidity sensor: There are two options, the ST's HTS221TR sensor as on the Sensor HAT board, or the Honeywell HMC5883L-TR. Both use the I2C bus.
- Differential Pressure sensor: Can be used for drone/aircraft Pitot tube for airspeed. Measurement Specialties (TE Connectivity) 4525DO-DS5AI030DP 5 volt sensor on the I2C bus. If this sensor is not used, a connector can be fitted in pin holes 1 to 4 for external I2C devices. There are provisions for both 3.3 volt and 5.0 volt operation of the differential sensor or external I2C connector.
- Audio Output: GPIO13 has PWM audio filter, amplifier, and connector for direct speaker drive.
- Microphone: Knowles SPH0645LM4H-B on the I2S bus.
- Time of Day Clock: Maxim DS3231S using the GPS Super Cap/Battery Backup.
- Maxim 1-Wire bus controller.
- Quad tachometer Input: compatible with Spektrum SPM1452 sensors. Uses an Analog Devices ADT7470. There are provisions for other tachometers operating from 3.3 or 5.0 volts.
- Maxim secure memory for secure authentication applications.
- Connectors and buffers for cascadible, serial, RGB LEDs.
- Most I/Os have ESD protection.

Power

The PyFly board runs from a 5.0 volt to 12.0 volt maximum input on connector P1. The breakdown voltage of the input protection TVS is 12.2 volts and this voltage should never be exceeded. The input is protected from ESD to 15kV non-contact. If the high side drivers on J6 are not used, the input voltage can go as low as 3.0 volts. The power input connector is a Deans Ultra Plug; a small, lightweight, high current connector that is widely available. There is no battery charger on the PyFly.

The input power is converted to 5.1 volts through a buck-boost DC-DC converter. It is then further regulated to 3.3 volts with a linear regulator. The 5.1 powers the A/D converter analog voltage and the 3.3 volt powers most of the sensors.

The high side drivers on J6 are powered directly from the power input on P1. This is required since the high side driver can source as much as 42 amps for short periods. Care must be taken for high current applications if you use a LiPo battery. Most LiPo batteries have a built-in over-current protection. If your application exceeds this value, your battery will automatically disconnect and the PyFly and Raspberry Pi computer will lose power.

The servos that can connect to P2 and P3 can run directly off the power input or can run two diode drops below the power input. This is selected by W4. For all but the smallest servos, it is recommended that W4 be a soldered wire short, not a removable jumper due to current requirements. LiPo battery voltages and servo voltage options are listed below:

LiPo cell count	**W4 position**	**Servo voltage**
1 (3.0V - 3.7V)	1-2	1.8V – 2.7V
1 (3.0V - 3.7V)	2-3	3.0V - 3.7V
2 (6.0V – 7.4V)	1-2	4.8V – 6.4V
2 (6.0V – 7.4V)	2-3	6.0V – 7.4V
3 (9.0V – 11.1V)	1-2	7.8V – 10.1V
3 (9.0V – 11.1V)	2-3	9.0V – 11.1V

Servos could be powered independently by wiring an external power source to pin 2 on W4.

Compatibility

The PyFly is designed to be mated to a Raspberry Pi Zero, but is compatible with many Raspberry Pi 40-pin compatible computers. The intended connection to a Raspberry Pi Zero is soldering a dual row 40 pin header from the bottom side of the Raspberry Pi Zero to the ‘solder’ side of the PyFly at J1. This allows the boards to be 1.6mm apart for the tightest form factor. The I2C_0 bus has an EEPROM for storing a device tree, but there currently isn’t a device tree definition for the EEPROM. Below is a list of other 40 pin computer boards that may offer some compatibility.

https://www.raspberrypi.org/products/pi-zero/
https://www.raspberrypi.org/products/raspberry-pi-3-model-b/
https://www.pine64.org/?product=pine-a64-board-2gb
http://www.orangepi.org/orangepiplus2e/

All the connections to the host computer through the 40 pin connector have a small capacitor to prevent any RF ingress to the Host since the PyFly has a RF transmitter.

J8 is a reset pin that lines up with the reset pin on a Raspberry Pi Zero. This allows the reset to

be kept low until adequate power is available to run. This can be useful for solar applications.

RF Transmitter Amplifier & Filter

The PyFly board has two RF outputs. Each one has its own filter for a specific RF band. The default build is for the 144MHz HAM band and the 440MHz HAM band. 144MHz transmission can be supported by pifm, nbfm, and rpitx. 440MHz transmission may someday be supported by rpitx on the Raspberry Pi Zero, but currently does not work. Rpitx works well on the Raspberry Pi 3. There has been no testing on other 'compatible' computers. Supports RF carrier from either GPIO4 or GPIO18 (also the I2S clock) selected with GPIO27 if R116 is installed. The on-board microphone can't be used with GPIO18 selected as the RF output. Below is a table for the multiplexor and the band.

GPIO27	**Selected Timer Output**	**Supporting Software**
Low	GPIO18 (shared with I2S)	rpitx
High	GPIO4	pifm, nbfm, rpitx

Band	**TX Output Connector**	**Supporting Software**
144	J3	pifm, nbfm
433	J2	rpitx

The RF transmitter can transmit APRS location data using pkt2wave and nbfm programs.
See Appendix C for additional information.

Servo Outputs

The PyFly has eight servo outputs on P2 and P3. Please read the above Power section to properly match your board power to your servo voltage requirements. The servo PWM pulses are generated by a Qualcomm (NXP) PCA9685PW. Only eight of the sixteen outputs are used, and the outputs are not in order with respect to the data sheet ordering. It is intended that a software driver should handle the assignments. There is no software overhead to keep a servo in a given position, as the PCA9685PW will continue generating the same pulse width until commanded to a new pulse width. The pulse width can be clocked with an external 12.000MHz oscillator, U11, for consistent, temperature stable operation, or the PCA9685's internal oscillator may be used. It is recommended that the programmed ON time of each PWM is distributed evenly across the 4096 clock period to reduce large current spikes from the servo motors. Below is the setup requirements and servo PWM performance information when operated from optional oscillator U11.

Prescaler=49
Update rate= 12000000/4096/49=59.79Hz
Minimum adjustment=1/(12000000/49)=4.0833µs
Full servo throw=1ms (+/- 0.5ms)
% adjustment per count=4.08333µs/1ms=0.4083%

Pulse width	*Off time* minus *On time*
0.4ms	98
0.5ms	122
1.0ms	245
1.5ms	367
1.6ms	392

The servo PWM pins have ESD protection. See Appendix C for additional information.

High Current Outputs

The PyFly board has four 42 amp peak current outputs. It is important to understand that these are not continuous 42 amp drivers. Any load over five amps must be momentary as there is not enough heat sinking on the high side driver. The load current of each output is monitored by the A/D converter allowing the software to protect against overloads. Each output is designed to drive a high current igniter like what is used for igniting an upper stage rocket motor or deploying a parachute. The output are also suitable for running a DC fan, lights, or any DC load that won't over heat or exceed the inductive kick back capability of the VNQ5027AKTR-E.

At power up the high current outputs are not enabled. There is a flip-flop that is set to disable the outputs at power up. The only way to enable the outputs is to set all four of the Fire outputs to zero (inactive) and then make a low to high transition on the FireEnableEdge (GPIO25) output. This circuit prevents any single random write to the fire control lines from turning on an output. This protection circuit is designed for applications where only one set of outputs is active at a time, and then turned off, like rocket igniter applications. To keep this protection active between ignition events the turn-on, turn-off sequence must be:

Turn on:
1) All Fire outputs (Fire A to Fire D) must be low
2) Make a low to high transition on FireEnableEdge
3) Set required Fire output high to provide output power to required outputs

Turn off:
1) Set the FireEnableEdge low
2) Make a low to high transition on FireEnableEdge, this will shut off the driver
3) Set all Fire A to Fire D outputs low.
4) This leaves the fire control immune to any single errant write of the GPIOs.

If protection is not required for your application, after enabling with FireEnableEdge, the individual Fire outputs may be activated or negated at will.

For A/D measurements of output current or voltage, see the A/D section. See Appendix C for more information.

The servo PWM pins have ESD protection.

Headless Operation

The PyFly board has support for headless operation. There is a momentary push button on GPIO26 to request an orderly shutdown of the Raspberry Pi. There is also a LED that can be used to indicate that the software has received the request and is working on the shutdown. Here is a link to a tutorial on the Adafruit software for an external shutdown request. The software needs to be altered for using GPIO26 for the request and GPIO16 for the LED. In addition to the push button requesting a shutdown, there is a battery voltage comparator that can also request a shutdown if the input voltage gets too low. This is useful for remote applications such as solar powered installations or solar power recharged battery applications. If W5 is shorted, the comparator can request a shutdown when the input voltage falls below 3 volts. See Appendix C for additional information.

USB Connector

The PyFly board doesn't have any USB electronics but it does allow the Raspberry Pi Zero's USB port to be 're-located to a type A connector that is mounted at the end of the PyFly board. This allows using a USB device in a narrow tube like a rocket body tube. Using this connector requires soldering three small wires from three test points on the Raspberry Pi Zero to three pads on the PyFly. This connection is not compatible with any other computer than the Raspberry Pi Zero or Raspberry Pi Zero W.

The USB connector has ESD protection.

GPS

The PyFly board has a GPS receiver and SMA connector for an external antenna. Antenna preamp power is provided (3.3V) so either an active or passive antenna may be used. The RF input has an amplifier and a bandpass filter to prevent de-sense to the RF front end from the local transmitter. Below is a list of omnidirectional helical antennas, The Richardson RF antenna was used for design validation.

Active antennas:

http://www.stepglobal.com/maxtena-m1227hct-a-l1-l2-gps-glonass-compact-active-helix-antenna
https://www.radiall.com/antennas/standard-short-gps-l-1-active-25db.html

Passive antennas:
http://www.richardsonrfpd.com/Pages/Product-Details.aspx?productId=1142163
http://www.stepglobal.com/maxtena-m1516hct-p-sma-l1-gps-glonass-compact-passive-helical-antenna

The GPS receiver powers up in standard NMEA-0183 format supporting GGA, GLL, GSA, GSV, RMC, VTG, ZDA sentences. The baud rate may be increased to 115200 and the protocol changed to SkyTraq Binary, and the update rate may be set as high as 50 locations per second. The libpifly library sets the GPS to 50 readings a second in binary mode.

There are three options for back-up power for the almanac and ephemeris, a small SMT super capacitor (C2), a larger through-hole super capacitor (C58), or a external connection for a battery (P7). The slower Skytraq Venus638 may be used in place of the Venus838 by changing R74 & R108.

The board may be assembled without the SkyTraq GPS and have the serial port available for another purpose, or an external GPS by using connector P6. See Appendix C for additional information.

Analog to Digital Converter

The PyFly has a 16 channel A/D converter. The design is compatible with 8, 10, and 12 bit versions of the A/D converter. The default build is with the 10 bit version. The A/D driver should always read the converter so the data is left justified, putting DO-11 (bit position from the data sheet), the MSB, in the most significant bit of the processors register. The math will assume the binary point is just to the left of the most significant bit. This will make all data returned from the A/D converter a fraction from 0.0000 to, but not including, 1.0000. This will be true for any of the available resolutions. In the table below, <A/D> is always this fraction from 0.0000 to 1.0000.

Channel	Measurement	Conversion to Engineering Units
0	AnalogCH1, J7 pin 3	Application dependent
1	AnalogCH2, J7 pin 3	Application dependent
2	AnalogCH3, J7 pin 3	Application dependent
3	AnalogCH4, J7 pin 3	Application dependent
4	AnalogCH5, J7 pin 3	Application dependent, if thermistor, see appendix B
5	AnalogCH6, J7 pin 3	Application dependent, if thermistor, see appendix B
6	PyFly temperature	See appendix B
7	Keypad	See Keypad section below
8	Fire A current	<A/D> * 54.217 amps (using 5V reference)
9	Fire B current	<A/D> * 54.217 amps (using 5V reference)
10	Fire C current	<A/D> * 54.217 amps (using 5V reference)
11	Fire D current	<A/D> * 54.217 amps (using 5V reference)

12	Fire D output voltage	<A/D> * 30 volts (using 2.5 volt reference)
13	Fire C output voltage	<A/D> * 30 volts (using 2.5 volt reference)
14	Fire B output voltage	<A/D> * 30 volts (using 2.5 volt reference)
15	Fire A output voltage	<A/D> * 30 volts (using 2.5 volt reference)

This device is on the higher speed SPI bus so rapidly changing data can be captured accurately. The SPI address is SPI_ADDR1..0=0x2. See Appendix C for additional information.

There is a small breakout board for the A/D converter analog input connector. This adapts the 0.050" pitch connector to some 0.10" connectors and also provides a voltage reference for additional thermistors or other sensor excitation. See figure 2.

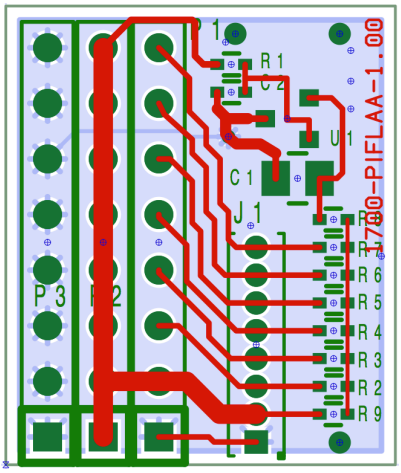


figure 2

Keypad Support

The PyFly board has a dedicated keypad connector. This connector supports a analog 1-wire keypad. There is a 7-resistor voltage divider that different keys short different combinations of resistors, to provide a unique voltage for each key. This connector has a resistor array that can be built two ways, first for a 6 key keypad with a single common, and second for a 3 x 4 matrix. For larger keypad requirements you will need to use an external resistor divider. Using 1% resistors keypads as large as 26 keys can be realized. Software to generate the keypad decode software can be found at:

http://rau-deaver.org/1-wire_keyboard.html

Below in figure 3 is a picture of the application with the A/D and resistor values filled in for the PyFly. Typically the application is used to take an A/D specification and keypad layout and give you resistor values, but that was done at the design of the PyFly. You just need to replace the values and generate your C code. One source for keypads with a compatible connector is XYMOX. See:
http://www.xymox.com/stock-membrane-switches

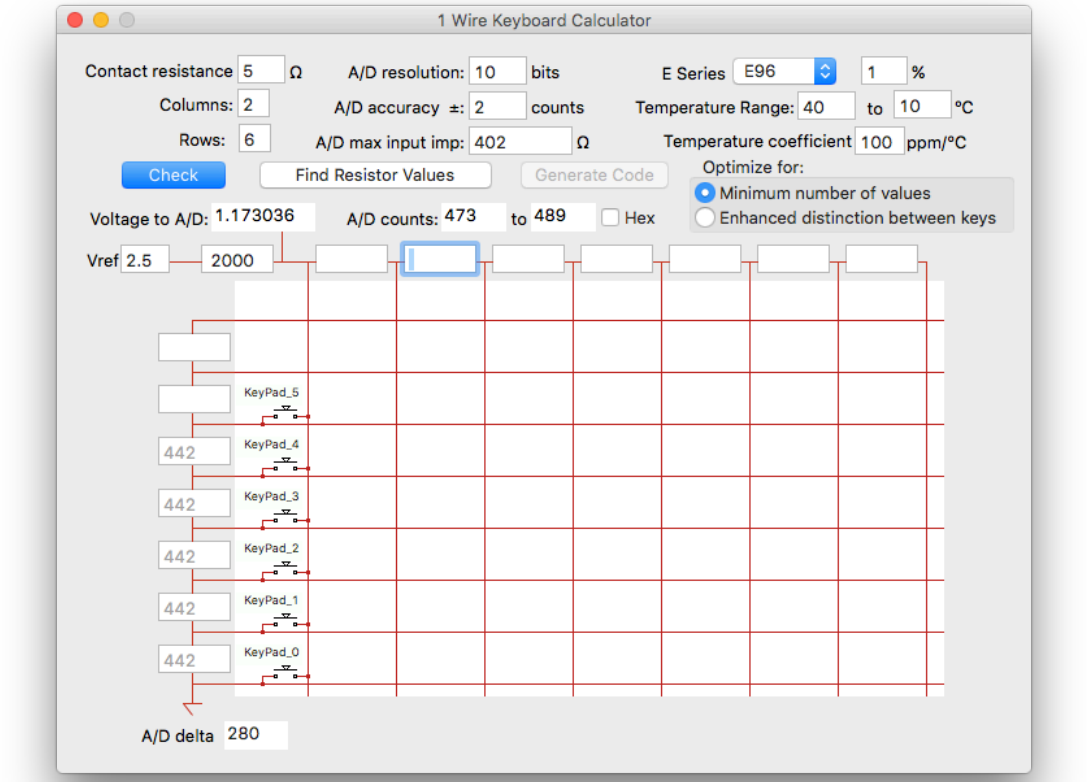


figure 3

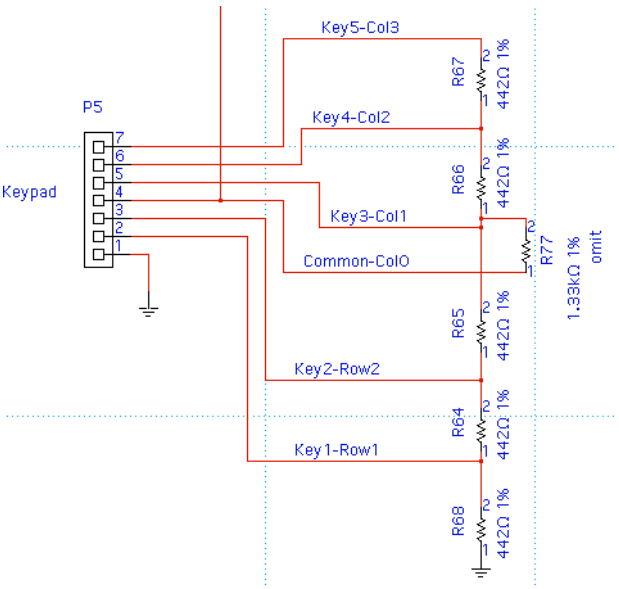
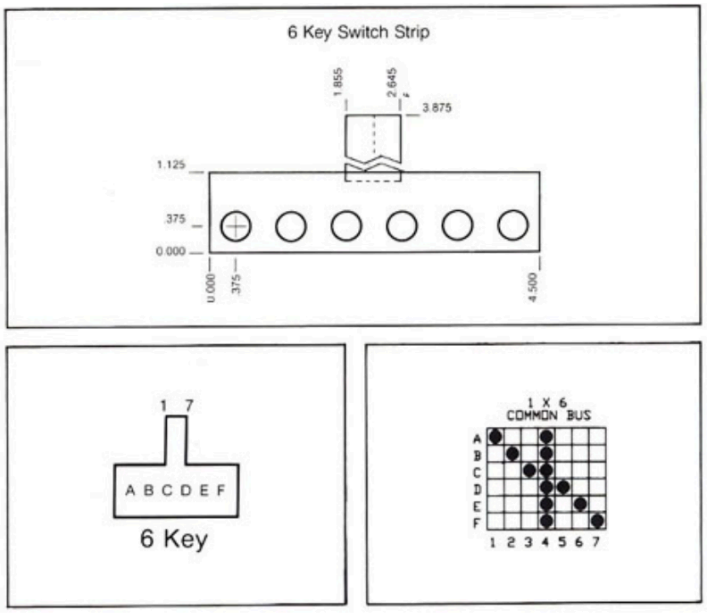


figure 4



Catalog Numbers

Termination*	1x4 common	5 Key	6 Key
Without Connector	14082	14122	14182
With Connector	14084	14124	14184

figure 5

For a 3x4 keypad like a XYMOX part number 12654:
R65 no pop
R77 populate with 1.33kΩ
R69 change to 4.75kΩ
R66 change to 1.33kΩ
R67 change to 1.33kΩ

High G linear accelerometer

The PyFly board has an accelerometer for high acceleration application like rocketry. The device is mounted so –X acceleration is in the direction of the USB connector end of the board. This device is on the higher speed SPI bus so rapidly changing data can be captured accurately. The SPI address is SPI_ADDR1..0=0x1. See Appendix C for additional information.

Barometric Pressure Sensors

The PyFly board has two options for barometric pressure sensing. The first option is the ST Microelectronics LPS25HBTR, the second option is the TE Connectivity MS560702BA03-00. The LPS25HBTR has the advantage of compatibility with the Sensor Hat board and higher accuracy. The MS560702BA03-00 has the advantage of operation to -40°C and higher read rate with its SPI interface.
See Appendix C for additional information.

9 Axis Inertial and Magnetic Platform

The PyFly board uses an Invensense (TDK) MPS-9250 for 3-axis acceleration, 3-axis gyro, and 3-axis magnetometer. Mounted on board centerline making it easier for the sensor to be on the centerline or your center of mass of your rocket/drone so you don't have to mathematically back out roll accelerations. Mounted on board so +X acceleration is towards the GPS Antenna end of the board and +Y is towards the 40 pin Raspberry Pi connector. Uses I2C bus at address 0b1101001. See Appendix C for additional information.

Humidity sensor

Uses ST's HTS221TR sensor as on Raspberry Pi's Sensor HAT board. Uses I2C bus at address

0b1011111. See Appendix C for additional information.

Differential Pressure Sensor

For use with drone/aircraft Pitot tubes for airspeed. TE Connectivity 4525DO-DS5AI030DP sensor is used. This is a through hole device that mounts over some SMT components. Uses I2C bus at address 0b0101000. See Appendix C for additional information.

Audio Output

There is a two-pin connector for headphone or speaker level audio output. See Appendix C for additional information.

Microphone

Knowles SPH0645LM4H-B on the I2S bus. The select pin is grounded so the microphone shows up on the Left channel. See Appendix C for additional information.

Time of Day Clock

To provide time for the PyFly built without a GPS or network access, the Maxim DS3231S is an optional device. Battery Backup is provided by the same source as the GPS battery backup. Uses I2C bus at address 0b0101000. See Appendix C for additional information.

Quad tachometer input

Useful for quadcopter motor speed sensing. Four channel tachometer input compatible with Spektrum SPM1452 sensors. Uses an Analog Devices ADT7470. With resistor changes the ADT7470 also supports GPIOs and a digital temperature sensor bus that can optionally be enabled at the expense of tachometer channels. This footprint is also compatible with the ON Semiconductor ADT7460 that supports low voltage level tachometer inputs. Uses I2C bus at address 0b0101110. See Appendix C for additional information.

Appendix A Connector Descriptions

J1 – Raspberry Pi 40 pin connector – Dual row 0.10” pin header

Signal	Pin No.	Signal	Pin No.
3.3V (unused)	1	MISO	21
Plus5V	2	FireEnableEdge	22
KS_SDA	3	SPI_CLK	23
Plus5V	4	SPI_ADDR0	24
KS_SCL	5	Ground	25
Ground	6	SPI_ADDR1	26
KS_RF_144	7	ID_SD	27
KS_GPS_RXD	8	ID_SC	28
Ground	9	Interrupt_GPIO5	29
GPS_TXD	10	Ground	30
FIRE_AR	11	TX_EN	31
KS_I2S_Clk	12	Interrupt_GPIO12	32
RF_SEL	13	PWM_AudioOut	33
Ground	14	Ground	34
FIRE_BR	15	I2S_WS	35
FIRE_CR	16	Shutdown_LED	36
Enable3.3	17	Shutdown_SW	37
FIRE_DR	18	I2S_DataIn	38
SPI_MOSI	19	Ground	39
Ground	20	GPS_RSTn	40

J2 – 440 – Cinch 128-0711-201 coax connector

440MHz Out	Center
Ground	Shield

J3 - 144 – Cinch 128-0711-201 coax connector

144MHz Out	Center
Ground	Shield

J4 – USB – Type A right angle USB connector

Plus5V	1
USB_D-	2
USB_D+	3
Ground	4

J5 – GPS – SMA connector

GPS_Antenna	Center
Ground	Shield

J6 – High Current Outputs – Press-to-open terminal block

FireD	1
Ground	2
FireC	3
FireB	4
Ground	5
FireA	6

J7 - Analog In – Single row 0.050” female connector

Ground	1
Plus5V	2
AnalogCH1	3
AnalogCH2	4
AnalogCH3	5
AnalogCH4	6
AnalogCH5	7
AnalogCH6	8

J8 – RES – Single 0.025” pin that is located to connect with the Raspberry Pi Zero reset pad

PowerGood	1

P1 – LiPo – Deans Ultra male connector.

Ground	–
PlusLiPo	+

P2 - Servos 5 to 8 – Three row 0.10” pin header

Ground	1
ServoPower	2
Servo8	3
Ground	4
ServoPower	5
Servo7	6
Ground	7
ServoPower	8
Servo6	9
Ground	10
ServoPower	11
Servo5	12

P3 - Servos 1 to 4 – Three row 0.10” pin header

Ground	1
ServoPower	2
Servo4	3
Ground	4
ServoPower	5
Servo3	6
Ground	7
ServoPower	8
Servo2	9
Ground	10
ServoPower	11
Servo1	12

P4 – Audio Out – Two pin 0.10” pin header

Audio Out +	1
Audio Out -	2

P5 – Keypad – single row 7 pin 0.10” pin header

Ground	1
Key1-Row1	2
Key2-Row2	3
Common-Col0	4
Key3-Col1	5
Key4-Col2	6
Key5-Col3	7

P6 – Serial - single row 4 pin 2mm pin header

Ground	1
GPS_RXD	2
GPS_TXD	3
Plus3.3V	4

P7 - GPS Battery – Two pin 0.10” pin header

Ground	1
Batt	2

P8 - Tach In – Three row 0.10” pin header

Ground	1
Plus5V/3.3V	2
Tach 1	3
Ground	4
Plus5V/3.3V	5
Tach 2	6
Ground	7
Plus5V/3.3V	8
Tach 3	9
Plus5V/3.3V	10
Plus5V	11
Tach 4	12

P9 - 1-Wire – Two pin 0.10” pin header

Ground	1
1-Wire	2

Appendix B Thermistor Conversion Table

Series pull up resistor	R76, R90, & R91	10	kΩ
A/D MAX count		1024	counts
Typical VddA		2.5	volts

Temp °C	R_{MIN} kΩ	R_{NOM} kΩ	R_{MAX} kΩ	Ratio	ADC Counts	Volts
-40	188.020	195.652	203.573	0.9514	974	2.378
-39	177.804	184.917	192.295	0.9487	971	2.372
-38	168.214	174.845	181.720	0.9459	969	2.365
-37	159.207	165.391	171.798	0.9430	966	2.357
-36	150.744	156.513	162.486	0.9399	963	2.350
-35	142.788	148.171	153.742	0.9368	959	2.342
-34	135.306	140.330	145.527	0.9335	956	2.334
-33	128.266	132.958	137.807	0.9300	952	2.325
-32	121.640	126.022	130.548	0.9265	949	2.316
-31	115.400	119.494	123.720	0.9228	945	2.307
-30	109.522	113.347	117.294	0.9189	941	2.297
-29	103.989	107.565	111.252	0.9149	937	2.287
-28	98.773	102.116	105.561	0.9108	933	2.277
-27	93.851	96.978	100.198	0.9065	928	2.266
-26	89.207	92.132	95.142	0.9021	924	2.255
-25	84.823	87.559	90.374	0.8975	919	2.244
-24	80.682	83.242	85.876	0.8928	914	2.232
-23	76.770	79.166	81.630	0.8879	909	2.220
-22	73.072	75.316	77.620	0.8828	904	2.207
-21	69.576	71.677	73.834	0.8776	899	2.194
-20	66.269	68.237	70.255	0.8722	893	2.180
-19	63.148	64.991	66.881	0.8667	887	2.167
-18	60.192	61.919	63.689	0.8610	882	2.152
-17	57.393	59.011	60.669	0.8551	876	2.138
-16	54.742	56.258	57.811	0.8491	869	2.123
-15	52.228	53.650	55.104	0.8429	863	2.107
-14	49.846	51.178	52.541	0.8365	857	2.091
-13	47.586	48.835	50.112	0.8300	850	2.075
-12	45.442	46.613	47.810	0.8234	843	2.058

-11	*43.408*	44.506	*45.627*	0.8165	836	2.041
-10	*41.477*	42.506	*43.557*	0.8095	829	2.024
-9	*39.635*	40.600	*41.584*	0.8024	822	2.006
-8	*37.886*	38.791	*39.713*	0.7950	814	1.988
-7	*36.224*	37.073	*37.937*	0.7876	806	1.969
-6	*34.646*	35.442	*36.252*	0.7799	799	1.950
-5	*33.146*	33.892	*34.652*	0.7722	791	1.930
-4	*31.720*	32.420	*33.131*	0.7643	783	1.911
-3	*30.364*	31.020	*31.687*	0.7562	774	1.891
-2	*29.074*	29.689	*30.314*	0.7480	766	1.870
-1	*27.847*	28.423	*29.009*	0.7397	757	1.849
0	*26.678*	27.219	*27.768*	0.7313	749	1.828
1	*25.569*	26.076	*26.590*	0.7228	740	1.807
2	*24.512*	24.988	*25.470*	0.7142	731	1.785
3	*23.505*	23.951	*24.403*	0.7055	722	1.764
4	*22.545*	22.963	*23.386*	0.6966	713	1.742
5	*21.629*	22.021	*22.418*	0.6877	704	1.719
6	*20.756*	21.123	*21.494*	0.6787	695	1.697
7	*19.923*	20.267	*20.614*	0.6696	686	1.674
8	*19.127*	19.450	*19.775*	0.6604	676	1.651
9	*18.368*	18.670	*18.975*	0.6512	667	1.628
10	*17.643*	17.926	*18.211*	0.6419	657	1.605
11	*16.949*	17.214	*17.481*	0.6325	648	1.581
12	*16.287*	16.534	*16.784*	0.6231	638	1.558
13	*15.654*	15.886	*16.119*	0.6137	628	1.534
14	*15.049*	15.266	*15.484*	0.6042	619	1.511
15	*14.471*	14.674	*14.877*	0.5947	609	1.487
16	*13.918*	14.108	*14.298*	0.5852	599	1.463
17	*13.390*	13.566	*13.744*	0.5757	589	1.439
18	*12.884*	13.049	*13.215*	0.5661	580	1.415
19	*12.400*	12.554	*12.708*	0.5566	570	1.392
20	*11.937*	12.081	*12.224*	0.5471	560	1.368
21	*11.495*	11.628	*11.762*	0.5376	551	1.344
22	*11.070*	11.195	*11.320*	0.5282	541	1.320
23	*10.664*	10.780	*10.896*	0.5188	531	1.297
24	*10.274*	10.382	*10.489*	0.5094	522	1.273
25	*9.900*	10.000	*10.100*	0.5000	512	1.250
26	*9.534*	9.634	*9.734*	0.4907	502	1.227

27	*9.184*	9.284	*9.383*	0.4814	493	1.204
28	*8.848*	8.947	*9.047*	0.4722	484	1.181
29	*8.525*	8.624	*8.723*	0.4631	474	1.158
30	*8.216*	8.315	*8.413*	0.4540	465	1.135
31	*7.920*	8.018	*8.116*	0.4450	456	1.113
32	*7.637*	7.734	*7.831*	0.4361	447	1.090
33	*7.365*	7.461	*7.558*	0.4273	438	1.068
34	*7.104*	7.199	*7.295*	0.4186	429	1.046
35	*6.853*	6.948	*7.043*	0.4100	420	1.025
36	*6.613*	6.707	*6.801*	0.4014	411	1.004
37	*6.383*	6.475	*6.568*	0.3930	402	0.983
38	*6.161*	6.253	*6.345*	0.3847	394	0.962
39	*5.949*	6.039	*6.130*	0.3765	386	0.941
40	*5.744*	5.834	*5.924*	0.3684	377	0.921
41	*5.547*	5.636	*5.725*	0.3604	369	0.901
42	*5.358*	5.445	*5.533*	0.3526	361	0.881
43	*5.176*	5.262	*5.349*	0.3448	353	0.862
44	*5.002*	5.086	*5.172*	0.3371	345	0.843
45	*4.833*	4.917	*5.002*	0.3296	338	0.824
46	*4.672*	4.754	*4.837*	0.3222	330	0.806
47	*4.516*	4.597	*4.679*	0.3149	322	0.787
48	*4.366*	4.446	*4.527*	0.3078	315	0.769
49	*4.222*	4.301	*4.381*	0.3007	308	0.752
50	*4.083*	4.161	*4.240*	0.2938	301	0.735
51	*3.950*	4.026	*4.104*	0.2870	294	0.718
52	*3.821*	3.896	*3.973*	0.2804	287	0.701
53	*3.698*	3.771	*3.847*	0.2739	280	0.685
54	*3.578*	3.651	*3.725*	0.2675	274	0.669
55	*3.463*	3.535	*3.608*	0.2612	267	0.653
56	*3.353*	3.423	*3.495*	0.2550	261	0.638
57	*3.246*	3.315	*3.386*	0.2490	255	0.622
58	*3.143*	3.211	*3.280*	0.2431	249	0.608
59	*3.044*	3.111	*3.179*	0.2373	243	0.593
60	*2.949*	3.014	*3.081*	0.2316	237	0.579
61	*2.858*	2.922	*2.988*	0.2261	232	0.565
62	*2.770*	2.834	*2.898*	0.2208	226	0.552
63	*2.686*	2.748	*2.812*	0.2156	221	0.539
64	*2.604*	2.666	*2.728*	0.2105	216	0.526

65	*2.526*	2.586	*2.648*	0.2055	210	0.514
66	*2.450*	2.509	*2.570*	0.2006	205	0.501
67	*2.377*	2.435	*2.495*	0.1958	201	0.490
68	*2.306*	2.364	*2.422*	0.1912	196	0.478
69	*2.238*	2.294	*2.352*	0.1866	191	0.467
70	*2.172*	2.228	*2.284*	0.1822	187	0.455
71	*2.109*	2.163	*2.218*	0.1778	182	0.445
72	*2.047*	2.100	*2.155*	0.1736	178	0.434
73	*1.987*	2.040	*2.093*	0.1694	173	0.424
74	*1.930*	1.981	*2.034*	0.1654	169	0.413
75	*1.874*	1.925	*1.976*	0.1614	165	0.403
76	*1.820*	1.870	*1.921*	0.1575	161	0.394
77	*1.768*	1.817	*1.867*	0.1538	157	0.384
78	*1.718*	1.766	*1.815*	0.1501	154	0.375
79	*1.670*	1.716	*1.764*	0.1465	150	0.366
80	*1.623*	1.669	*1.716*	0.1430	146	0.357
81	*1.577*	1.622	*1.669*	0.1396	143	0.349
82	*1.533*	1.578	*1.623*	0.1363	140	0.341
83	*1.491*	1.535	*1.579*	0.1330	136	0.333
84	*1.450*	1.493	*1.537*	0.1299	133	0.325
85	*1.410*	1.452	*1.495*	0.1268	130	0.317
86	*1.372*	1.413	*1.455*	0.1238	127	0.309
87	*1.334*	1.375	*1.417*	0.1209	124	0.302
88	*1.298*	1.338	*1.379*	0.1180	121	0.295
89	*1.264*	1.303	*1.343*	0.1152	118	0.288
90	*1.230*	1.268	*1.307*	0.1125	115	0.281
91	*1.197*	1.234	*1.273*	0.1099	113	0.275
92	*1.165*	1.202	*1.240*	0.1073	110	0.268
93	*1.134*	1.170	*1.207*	0.1047	107	0.262
94	*1.104*	1.139	*1.176*	0.1023	105	0.256
95	*1.075*	1.110	*1.146*	0.0999	102	0.250
96	*1.046*	1.081	*1.116*	0.0975	100	0.244
97	*1.019*	1.053	*1.088*	0.0953	98	0.238
98	*0.993*	1.026	*1.060*	0.0930	95	0.233
99	*0.967*	0.999	*1.033*	0.0909	93	0.227
100	*0.942*	0.974	*1.007*	0.0887	91	0.222
101	*0.918*	0.949	*0.982*	0.0867	89	0.217
102	*0.895*	0.925	*0.957*	0.0847	87	0.212

103	*0.872*	0.902	*0.933*	0.0828	85	0.207
104	*0.850*	0.880	*0.910*	0.0809	83	0.202
105	*0.829*	0.858	*0.888*	0.0790	81	0.198
106	*0.808*	0.837	*0.866*	0.0772	79	0.193
107	*0.788*	0.816	*0.845*	0.0755	77	0.189
108	*0.769*	0.796	*0.825*	0.0738	76	0.184
109	*0.750*	0.777	*0.805*	0.0721	74	0.180
110	*0.731*	0.758	*0.786*	0.0705	72	0.176
111	*0.714*	0.740	*0.767*	0.0689	71	0.172
112	*0.696*	0.722	*0.749*	0.0673	69	0.168
113	*0.679*	0.705	*0.731*	0.0658	67	0.165
114	*0.663*	0.688	*0.714*	0.0644	66	0.161
115	*0.647*	0.672	*0.697*	0.0629	64	0.157
116	*0.632*	0.656	*0.681*	0.0615	63	0.154
117	*0.617*	0.640	*0.665*	0.0602	62	0.150
118	*0.602*	0.625	*0.649*	0.0588	60	0.147
119	*0.588*	0.611	*0.634*	0.0575	59	0.144
120	*0.574*	0.596	*0.620*	0.0563	58	0.141
121	*0.561*	0.583	*0.605*	0.0551	56	0.138
122	*0.548*	0.569	*0.592*	0.0539	55	0.135
123	*0.535*	0.556	*0.578*	0.0527	54	0.132
124	*0.523*	0.544	*0.565*	0.0515	53	0.129
125	*0.511*	0.531	*0.552*	0.0504	52	0.126

Appendix C Software Book from Schematic

NOTE: All I2C addresses are binary 7 bit, usually B7..1. B0 is a R/W bit.

PyFly HAT Board Software Book

Overview

The PyFly board has 9 busses or signal groups:
1) The GPIO lines not associated with busses
2) I2C_0 bus for Raspian device tree
3) I2C_1 for sensors
4) I2S bus for microphone
5) SPI bus for high G acceleration sensor, absolute pressure sensor, & 16 channel, 8/10/12 bit A/D converter
6) UART for GPS
7) The LED bus to control external RGB LEDs.

Initialization Notes

Fire_A to Fire_D high current drivers will not work until they have been enabled, see GPIO25. If GPS almanic memory is backed up with a supercap, cold starts are typical after several hours without power. There is a connector for a battery.

Device data in bus order

Bus	Address	Location	Manufacturer	Part Number	Description	Info	Link
GPIO	Fire_A: GPIO17, Fire_B: GPIO22, Fire_C: GPIO23, Fire_D: GPIO24	U13 on page 7	ST Microelectronics	VNQ5027AKTR-E	IC,Digital,Interface,High Side Driver,Quad,	Quad High current high side driver.	For additional information see the VNQ5027 Data Sheet

GPIO	GPIO4	PCB8 on page 5	none	none	Software Note	To transmit on 2M band: sudo ./nbfm <> 144.39 <	For additional information see the Data Sheet
GPIO	GPIO4	PCB9 on page 5	none	none	Software Note	To generate a wave file of a packet modem: ./pkt2wave fox_pkt.txt -n 1 -r 44100 -o fox_pkt.wav	For additional information see the Data Sheet
GPIO	GPIO5	W1 on page 5	Samtec	TMM-103-03-L-S	Connector,Male,2mm,Gold	Sensors can route their interrupts/status to GPIO5 or GPIO12 using W1, W2 or W3. GPIO12 shared with RGB LED interface.	For additional information see the Data Sheet
GPIO	GPIO6	D10 on page 5	Osram	LS Q971	LED,Chip,0603,Red	LED D10 on with TX_EN.	For additional information see the TX Data Sheet
GPIO	GPIO6	D15 on page 5	Osram	LS Q971	LED,Chip,0603,Red	LED D10 on when high side drivers are enabled	For additional information see the ARM Data Sheet
GPIO	GPIO6	Q3 on page 5	ON Semiconductor	MUN5230DW1T1G	Transistor,NPN,Dual,Plastic,SOT-363,W/ bias resistors	A high on GPIO6 will power the RF transmitter and light LED D10	For additional information see the MUN5230D Data Sheet
GPIO	GPIO12	W2 on page 5	Samtec	TMM-103-03-L-S	Connector,Male,2mm,Gold	Sensors can route their interrupts/status to GPIO5 or GPIO12 using W1, W2 or W3. GPIO12 shared with RGB LED interface.	For additional information see the Data Sheet
GPIO	GPIO13	PCB4 on page 5	none	none	Software Note	For Audio output on GPIO13.	For additional information see the Data Sheet
GPIO	GPIO16	D7 on page 5	Kingbright	APTD1608ZGC	LED,Chip,Green,60° Viewing Angle	SW turns LED on to acknowledge	For additional informatio

						receiving shutdown button press	n see the SHUT ACK Data Sheet
GPIO	GPIO21	R56 on page 5	Vishay	CRCW0402200RFK	Resistor,Surface Mount,0402,1%,+/- 100ppm	GPS reset if R56 is installed	For additional information see the 200½ Data Sheet
GPIO	GPIO25	U21 on page 5	ON Semiconductor	NL17SZ74USG	IC,Digital,D Type Flip-Flop,Single,250MHz @ 5V	Enable for Fire_A to Fire_D. GPIO must make a positive edge while Fire_A to Fire_D are zero before any Fire signal will work.	For additional information see the NL17SZ74 Data Sheet
GPIO	GPIO26	PCB10 on page 5	none	none	Software Note	Push button for shutdown request.	For additional information see the Data Sheet
GPIO	GPIO27	U2 on page 5	Fairchild	NC7SV157P6X	IC,Digital,Multiplexor,2 Input	If R116 installed, GPIO27 selects the clock source to the RF amplifier. 0=GPIO18, 1=GPIO4. GPIO 27 shared with RGB LEDs	For additional information see the NC7SV157 Data Sheet
I2C_0	1010000	U23 on page 5	ON Semiconductor	CAT24C32YI-GT3	IC,Digital,Memory,EEPROM,Serial,I2C Bus,32k Bit	Device Tree EEPROM bus	For additional information see the CAT24C32 Data Sheet
I2C_1	0011000	PCB13 on page 9	none	none	Software Note	1-Wire setup	For additional information see the Data Sheet
I2C_1	0011000	U27 on page 9	Maxim Integrated	DS2482S-100+	IC,Digital,I2C to 1-Wire Interface	Maxim 1 wire interface	For additional information see the DS2482 Data Sheet
I2C_1	0101000	U8 on page 5	Measurement Specialties	4525DO-DS5AI030DP	Sensor,Pressure,Differential,Ported With Barbed Inlets,5Vsupply	Differential pressure for air speed	For additional informatio

							n see the 4525DO Data Sheet
I2C_1	0101110	U28 on page 9	Analog Devices	ADT7470ARQZ	IC,Digital,Fan & Temperature,Quad	Tachometer inputs, Options for GPIO and temperature sensors.	For additional information see the ADT7470 Data Sheet
I2C_1	0111011	U30 on page 5	Maxim Integrated	DS28C36Q+U	IC,Digital,Memory,Secure,8kb,ECC-256,FIPS 180,SHA-256,Two GPIO Bits	Secure memory	For additional information see the DS28C36 Data Sheet
I2C_1	1000000	PCB14 on page 9	none	none	Software Note	PCA9685PW setup	For additional information see the Data Sheet
I2C_1	1000000	U10 on page 9	NXP	PCA9685PW,118	IC,Digital,LED Driver,I2C,16 Outputs	Servo PWM Driver- Only channels 8 to 15 used, not in order. EXTCLK pin tied to 12.000MHz for a prescaler value of 49.	For additional information see the PCA9685 Data Sheet
I2C_1	1011100	U3 on page 5	ST Microelectronics	LPS25HBTR	Sensor,Pressure,Absolute,260-1260 hPa	Absolute pressure for pressure altitude (alternate)	For additional information see the LPS25H Data Sheet
I2C_1	1011111	U4 on page 5	ST Microelectronics	HTS221TR	Sensor,Humidity & Temperature, SMT	Relitive humidity	For additional information see the HTS221 Data Sheet
I2C_1	1101000	U26 on page 5	Maxim Integrated	DS3231S#	IC,Digital,Time Of Day Clock,Built-In Crystal	Time of day clock	For additional information see the DS3231 Data Sheet
I2C_1	1101001	PCB11 on page 5	none	none	Software Note	IMU data over a data pipeline	For additional information see the Data Sheet
I2C_1	1101001	PCB12 on page 5	none	none	Software Note	MPU-9250 Library	For additional information see the

							Data Sheet
I2C_1	1101001	U16 on page 5	Invensense	MPU-9250	IC,Sensor,9 Axis,I2C & SPI	3 axis gyro, 3 axis accelerometer, 3 axis magnatometer, mounted on board centerline.- Reg 55: ACTL=1, OPEN=0	For additional information see the MPU9250 Data Sheet
I2S	Select=0	U22 on page 5	Knowles	SPH0645LM4H-B	Sensor,Microphone,Digital Output,I2S	Audio input through I2S microphone, left channel	For additional information see the MIC Data Sheet
LED	GPIO12	U31 on page 5	NXP	XC7SET08GW,125	IC,Digital,Gate,And,TTL Thresholds On Inputs	Serial bus Data for APA102 RGB LEDs	For additional information see the XC7SET08 Data Sheet
LED	GPIO27	U32 on page 5	NXP	XC7SET08GW,125	IC,Digital,Gate,And,TTL Thresholds On Inputs	Serial bus clock for APA102 RGB LEDs	For additional information see the XC7SET08 Data Sheet
SPI	SPI_ADDR1..0=0 b00	U7 on page 5	Measurement Specialities	MS560702BA03-00	Sensor,Pressure,Absolute,SMT	Absolute pressure for pressure altitude	For additional information see the MS5607 Data Sheet
SPI	SPI_ADDR1..0=0 b01	U6 on page 5	ST Microelectronics	H3LIS331DLTR	Sensor,Acceleration,3 axis,High G, I2C/SPI Interface	High G accelerometer, 3 axis	For additional information see the H3LIS331 Data Sheet
SPI	SPI_ADDR1..0=0 b10	U18 on page 7	Texas Instruments	ADS7957SDBTR	IC,Linear,A/D,10 Bit, 16 Channel,SPI Interface	16 channel analog to digital converter. CH0=keypad, CH7=temperature, CH8=Current Fire_A, CH9=Current Fire_B, CH10=Current Fire_C, CH11=Current Fire_D, CH12=Voltage	For additional information see the ADS7957 Data Sheet

						Fire_A, CH13=Voltage Fire_B, CH14=Voltage Fire_C, CH15=Voltage Fire_D	
UART	UART	U1 on page 6	SkyTraq	Venus838FLPx-L	Module,GPS,50Hz Update Rate,-165dB Tracking Sensitivity	GPS, 9600 baud, 8N1	For additional information see the GPS Data Sheet

Appendix D Shunt Setup Table

Shunt	Schematic Page	Description
W1	5-5G	IMU interrupt select 2-1: IMU, U16, interrupt routed to GPIO5 2-3: IMU, U16, interrupt routed to GPIO12. Using GPIO12 precludes the use of GPIO12 for the serial RGB LEDs.
W2	5-7G	Pressure sensor U3 interrupt select 2-1: Pressure sensor, U3, interrupt routed to GPIO5 2-3: Pressure sensor, U3, interrupt routed to GPIO12. Using GPIO12 precludes the use of GPIO12 for the serial RGB LEDs.
W3	6-12C	1-2: GPS 1PPS to interrupt GPIO5
W4	4-5G	Servo power select. 2-1: Servos powered two diode drops below power input voltage 2-3: Servos powered directly from power input voltage
W5	5-3B	1-2: Low Battery Shutdown
R109/R110	9-4G	R109: Power tachometer sensors with 5.1 volts. R110: Power tachometer sensors with 3.3 volts.
R111/R112	9-6G	R111: Tachometer sensor output pulled up to 5.1 volts. R112: Tachometer sensor output pulled up to 3.3 volts.
R106	4-7B	R106: For stuffing options where little current is required on the 3.3 volt rail, U14 can be removed and R106 installed.
R38/R39	4-13D	R38: Differential pressure sensor U8 and 1-wire interface U27 powered from 5.1 volts. Five volt versions of U8 are required. R39: Differential pressure sensor U8 powered from 3.3 volts. 1-Wire interface not available. U17 can be replaced with R36 and R37.

R116	5-3B	R116: Allows selection of RF carrier using GPIO27. With R116, if GPIO27 is set low, the microphone can't be used.
R118/R119	5-13E	R118: Power RGB LEDs directly from power input. R119: Power RGB LEDs from 5.1 volts.
R74/R108	9-6G	R74: GPS boot select, install for Venus838 R108: GPS boot select, install for Venus638