PUTSI™ WiFi Telemetry Module

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For Software Revision: 0.2b

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Document Revision History

Date	Rev	Description
June 2023	0.1	Draft of dual mode operation
Sept, 2023	0.2	Updated to current firmware
	0.2a	Revised A/D input scalars, added large Allstar configuration section
	0.2b	Moved temperature measurement to a separate document
Oct, 2023	0.2c	Rebanded with ADRCS logo

Table 1 Revision History

Additional Documents

Number	Title
AN001	Measuring Temperature

Table 2 Additional Documents

Reference Documents

[1] gnu.org, "General Public Licence," [Online]. Available: https://www.gnu.org/licenses/gpl-3.0.en.html. [Accessed 25th February 2018].

[2] Analog Devices, "Low Voltage Temperatue Sensors," [Online]. Available: https://www.analog.com/media/en/technical-documentation/data-sheets/TMP35_36_37.pdf. [Accessed 20 09 2023].

[3] Ettus Research, "USRP Hardware Driver and USRP Manual," [Online]. Available: https://files.ettus.com/manual/page_transport.html. [Accessed 21 October 2020].

Glossary of Terms

PBX	Private Branch Exchange. A node in a telephone network that provides connectivity for a series of local extensions to a set of trunks.
VOIP	Voice over Internet Protocol. A system where telephone calls are placed, and audio is exchanged using the Internet Protocol.
PUTSI	PIC USB Telemetry System Interface
Wi-Fi	Wireless Fidelity implementing the IEEE 802.11x standards.
USRP	Universal Software Radio Peripheral
UDP	User Datagram Protocol
SMS	Simple messaging system
USB	Universal Serial Bus
PIC	A series of microcontrollers by MicroChip, Inc.

Intellectual Property Notice

Disclaimer

This document is a preliminary release for a product still in development and may be subject to change in future revisions. The software may be subject to unpredictable behaviour without notice. You are advised to keep a can of RAID™ Ant, Roach and Program Bug killer handy. Spray liberally on the affected area when needed.

Release notes

Initial Release version 0.1:

1. **Dual operating modes**
   The current firmware supports operation in both the Wi-Fi and USB modes, which can be used simultaneously.

2. **Bidirectional Digital I/O**
   Digital I/O is now supported in both directions in both communication modes.

3. **Bi-Colour Communications LED**
   The COM led can now be off, red, green or alternating to reflect the current state of the firmware.

4. **Wi-Fi Configuration Mode**
   The Wi-Fi parameters can be entered using a host mode and single web page.

Update Rev 0.2:

1. **Bugs Fixed**
   A bug was found in the configuration mode that disabled both Wi-Fi and USB modes. The configuration mode is entered automatically if this condition occurs.

2. **Wi-Fi setup shortened**
   The port numbers and auto configuration were removed from the Wi-Fi setup and implemented as compilation options. Port numbers are unlikely to change, and the auto configuration is only applicable to the Wi-Fi mode, so now it is always enabled.

Update Rev 0.2a:

1. **Bugs Fixed**
   Fixed bugs in ADC message and processing of Pin state messages. Input voltages were tested with Allstar, as well as alarms and output messages.

2. **Restart code added**
   Added code to the ID request message to perform a soft restart, in attempt to autonomously keep up with Allstar restarts.

Overview

The digital telemetry system is designed to gather data at a remote site by a reporting device which sends it over an IP network to a remote site, where it is written to a database to be displayed at will. The data content can be from an analog source using and off the shelf converter, or from a digital input such as an open door sensor. A mechanism is also in place to return data for digital outputs, which can be used to activate remote devices such as lights, switches, etc.

Packets are sent over an IP network using the USRP (Universal Software Radio Peripheral) [2] protocol, as user datagram packets (UDP), which does not require a connection to be maintained. Packets are acknowledged by the receiver by sending back an acknowledgement packet.

Two types of reporting devices for gathering data have been developed, the MaplePi FPGA controller and a standalone device which employs a PIC processor called PUTSI (PIC USB Telemetry System Interface) which can be used in conjunction with another device such as a Raspberry Pi or other computer over a USB connection, or it can transmit packets directly over a Wi-Fi connection.

The MaplePi FPGA controller has a driver for Allstar that has the telemetry functionality built in, which makes use of the on-chip 8 channel A/D converter, and with an additional module can implement up to 8 outputs and 3 inputs. The PUTSI is equipped with 8 analog inputs, and 5 digital inputs and outputs, and can implement the Chameleon functionality required by Allstar, or be used in a standalone mode.

The receiving site has a web-based interface and runs on a standalone server. Data from the reporting device is written to a database, which dynamically updates a web page when needed. Analog data is interpreted by a pre- and post-scalar formula into more ‘meaningful’ data, such as temperature in degrees Centigrade, Kelvin or Fahrenheit, and digital I/O can be represented as ‘real world’ devices.

Alarms can be generated that can be sent to key personnel using an external e-mail facility, or, if present, sent as a SIP message to an IP phone, or as an SMS message to a cell phone. The frequency of updates is completely programmable.

Hardware

Figure 1 illustrates the PUTSI (PIC USB Telemetry System Interface) standalone hardware module for telemetry gathering. It has a standalone processor and can be connected to an Allstar system with USB or directly to a hub using a Wi-Fi module. In the USB mode, it emulates the Chameleon device supported natively by Allstar.

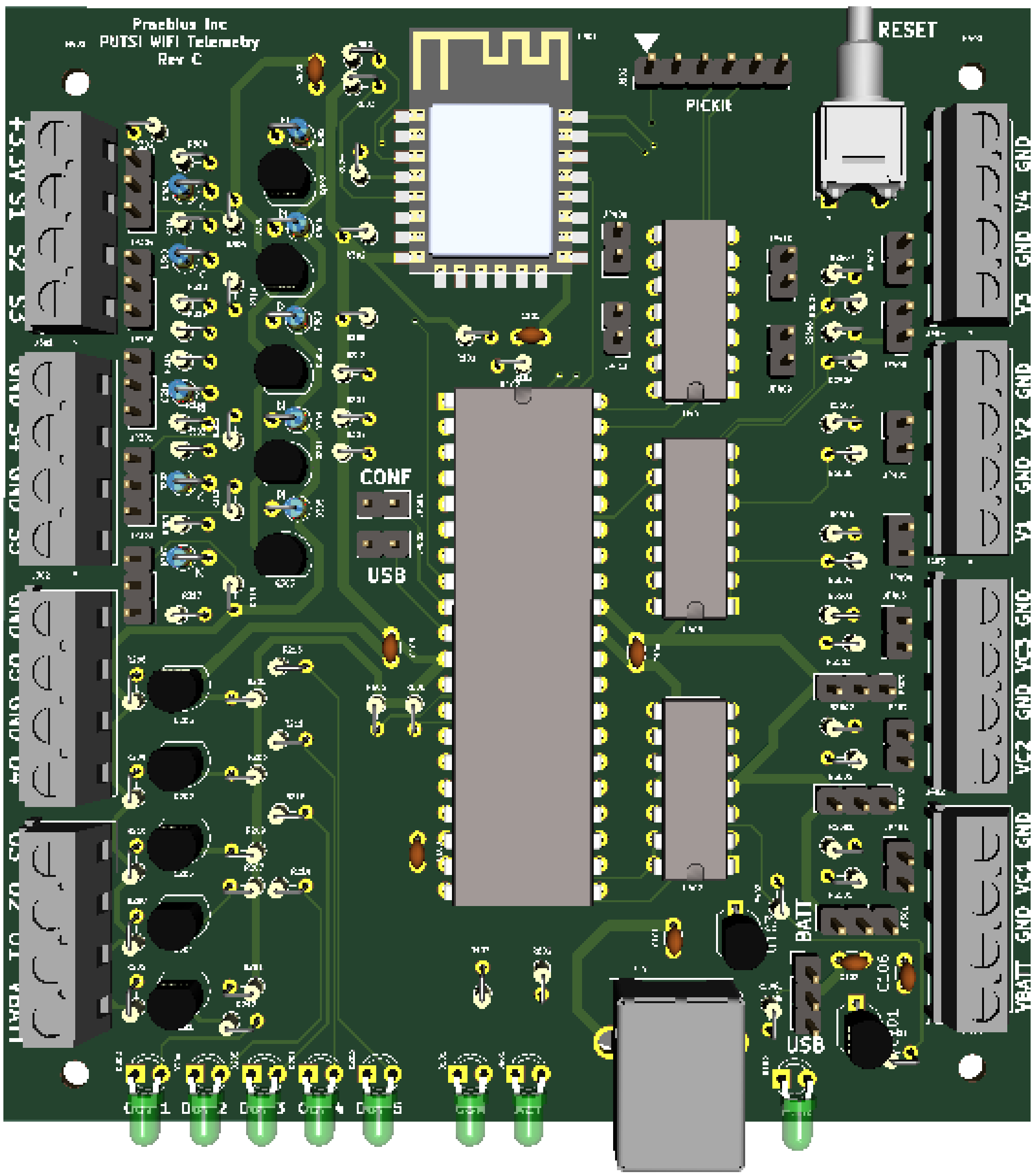

Figure 1 Pic based USB/Wi-Fi Telemetry Board (Rev C)

Specifications

The module can be powered either by the USB connection or a separate battery connection. The specifications are illustrated in Table 3.

Parameter	Min	Typ	Max	Units
Number of Analog Voltage inputs		4		
Number of Configurable Analog Channels		3		
Number of battery monitoring channels		1		
Number of uncommitted op amps		4		
Analog input voltage range	0		16[1]	V
Number of digital inputs		5		
Digital Input voltage range	0		vBatt	V
Number of digital outputs		5		
Output voltage range	0		vBatt	V
Output sink current			20	mA
Battery input voltage (vBatt)	5	12	16	V

Table 3 PUTSI module specifications

Power Options

The board can be powered either from the +5V supply on the USB cable, or from the VBATT terminals. Jumper JP101 determines which source is to be used, as illustrated in Table 4.

JP101 Jumper Settings	Power Source
1-2	+5V from the USB cable (recommended)
2-3	From the VBATT terminals (J401 1-2)

Table 4 Power Options

LED Indicators

There are 8 LED indictors as shown in Table 5.

LED Name	Purpose
CONN	Indicates that a Bluetooth connection has been established
PWR	Indicates power has been applied, through either source
COM	Indicates that the board is communicating with the host computer
OUT 1 to 5	One LED to show the status of each digital output

Table 5 LED indicators

[1] Higher voltages can be accommodated by adjusting Rg and Rs for the specific input.

Reset

There is a reset toggle switch beside the COM LED. Depressing it will reset the PIC processor, to re-establish communications the host software may need to be restarted.

Connectors

There are 8 connectors for inputs and outputs:

Connector	Pin	Desig	Purpose
J401	1	VBATT	Battery connection for power or monitoring
	2	GND	
	3	VC1	Configurable voltage input #1
	4	GND	
J402	1	VC2	Configurable voltage input #2
	2	GND	
	3	VC3	Configurable voltage input #3
	4	GND	
J403	1	V1	Analog input #1
	2	GND	
	3	V2	Analog input #2
	4	GND	
J404	1	V3	Analog input #3
	2	GND	
	3	V4	Analog input #4
	4	GND	
J201	1	VBATT	Battery voltage output
	2	O1	Digital Output #1
	3	O2	Digital Output #2
	4	O3	Digital Output #3
J202	1	O4	Digital Output #4
	2	GND	
	3	O5	Digital Output #5
	4	GND	
J302	1	S5	Sense Input #5
	2	GND	
	3	S4	Sense Input #4
	4	GND	
J301	1	S3	Sense Input #3
	2	S2	Sense Input #2
	3	S1	Sense Input #1
	4	VCC	Regulated +3.3V output

Table 6 Connector Pinouts

Converter Range

The A/D converter has a resolution of 3.3V/1024 per count. Using a resistor divider of 820/3300, the battery voltage can be scaled to fit into its linear range as shown in Figure 2.

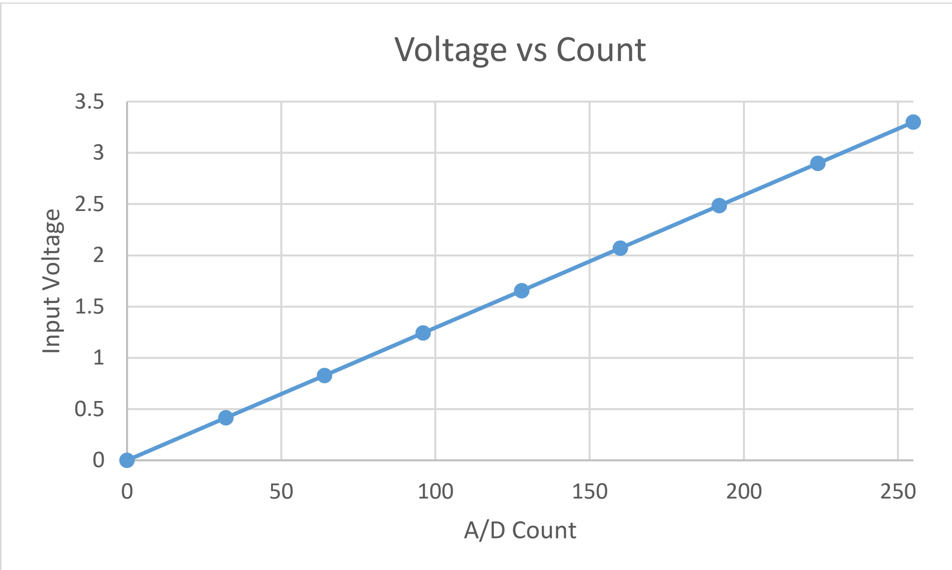

Figure 2 Input voltage vs A/D count.

Analog Inputs

At each input a dedicated op amp follower provides buffering before the converter. Figure 3 illustrates one of the analog voltage inputs:

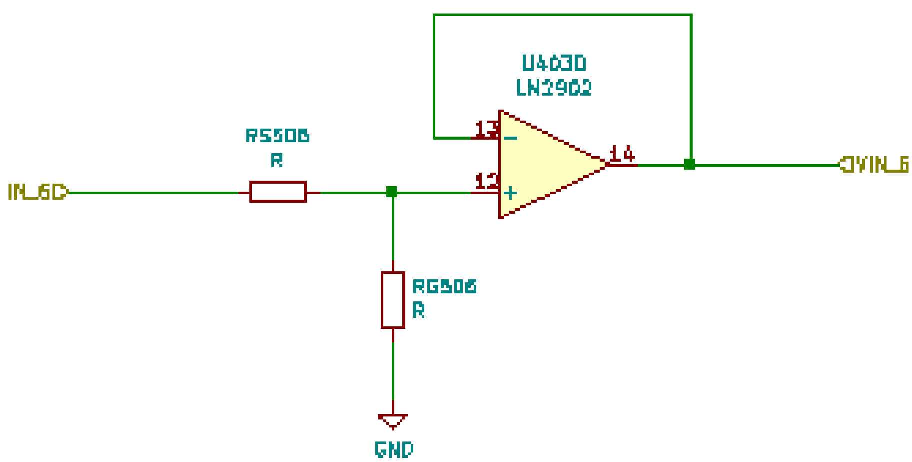

Figure 3 Analog input

Choosing the Resistor Divider Values

Resistors RS and RG (Series and Ground) implement a voltage divider to bring the analog voltage into operating range of the A/D converter, which can be from 0 to 3.3V.

The resistor values will vary depending on the maximum input value. It is recommended that the input voltage to the A/D not exceed 3.3V, so the divider value determines how the input value is scaled. In the monitoring software, a scalar value can be applied to the received value to restore the original voltage.

Table 7 lists recommended values based on a maximum input voltage. The scalar values shown can be used to restore the original voltage in the monitoring software.

Max Input Voltage	RS (Ω)	RG (Ω)	Max A/D Input	A/D max Count	Allstar Scalar	Scaled
24	3300	470	2.99	232	9.67	24
16	3300	820	3.18	247	15.44	16
14[2]	3300	910	3.03	234	16.71	14
8	3300	2200	3.20	248	31.00	8
6	3300	2900	2.81	217	36.17	6

Table 7 Recommended Resistor Values

The formula for calculating the resistor values is shown in the following equation:

$$3.3V = Vin \times \frac{Rs}{Rs + Rg}$$

For example, if a battery voltage was to be measured that had a maximum of 16V, the Rs can be calculated by first fixing Rg at a known value, and then solving for it. The recommended values of 820/3.3K will yield an approximate divide by five, which will work for most voltages used in repeater systems.

Each input has a jumper before the resistive divider. There are four uncommitted op amps configured as unity followers, and the jumper terminals can be connected to one of these to provide high impedance isolation of any input, before the divider.

[2] Default value for initial setup

Configurable Analog Inputs

Configurable inputs have a different circuit as illustrated in Figure 4. There is an additional jumper that enables the RG resistor to either act as a divider, when connected to ground, or as a voltage source when connected to Vcc.

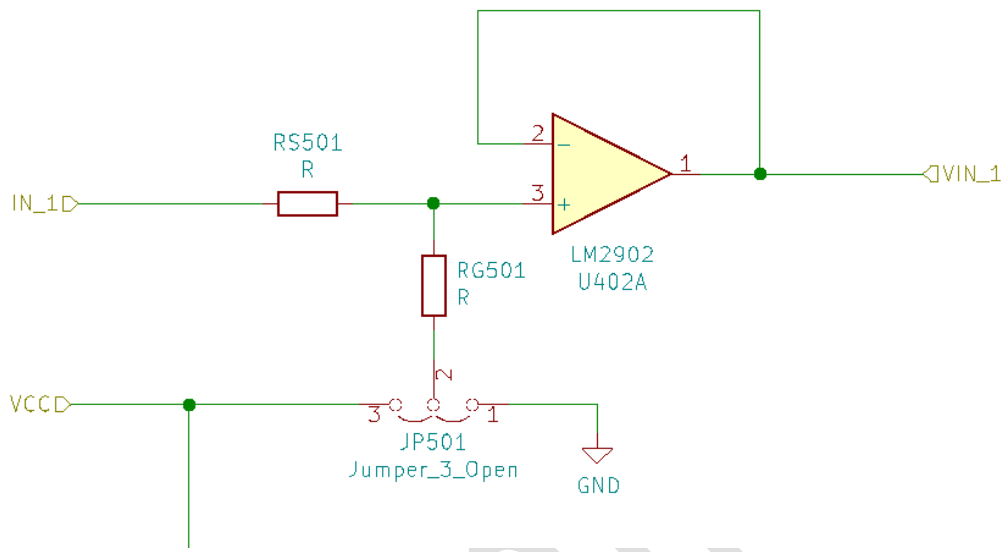

Figure 4 Configurable analog Input

A thermistor type temperature probe or active device can be configured for measuring temperatures, such as the shack, power amplifiers, etc. The recommended devices for temperature measurement is the TMP36 from Analog Devices [2], which retails for about $3.

For additional information, please consult document AN001: Measuring temperature.

Digital Inputs

Digital inputs can sense the presence of an analog voltage up to 12v, which can be hooked up to sense environmental changes such as a door being opened. A typical input circuit for each digital input is shown in Figure 5.

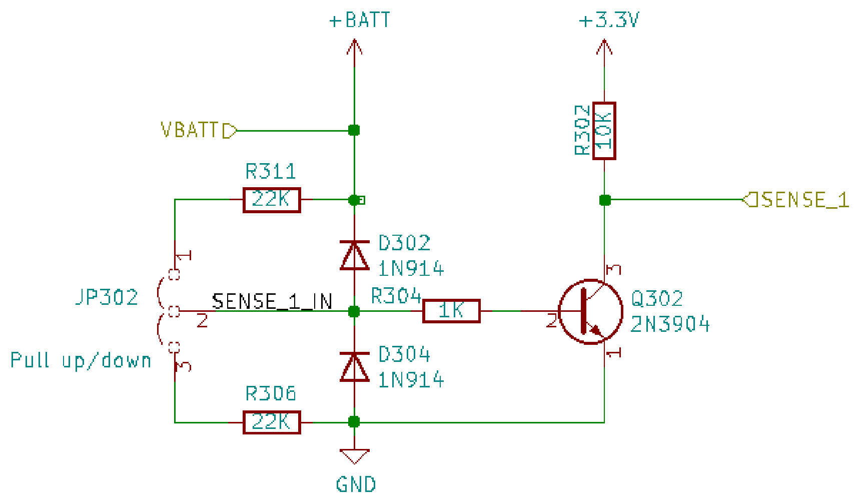

Figure 5 Digital input conditioning

Each input can be pulled up or down depending on the jumper setting. Following that a pair of protection diodes ensure that the voltage does not go below ground and above the battery voltage. It this were to occur it is clamped. The transistor buffers and inverts the input, the software removes this inversion. The quiescent voltage when pulled up is about 1V, it can be changed by modifying the pullup resistor value.

Digital Outputs

The circuit of a digital output is shown in Figure 6. Each has a light emitting diode (LED) to show its status and is buffered with a field effect transistor (FET). When the output from the microprocessor is at ground, the LED is turned off and no current is sourced to the gate of the FET, and the output rises to the battery voltage. When current is applied by the microprocessor, the LED is lit up and the FET is turned on.

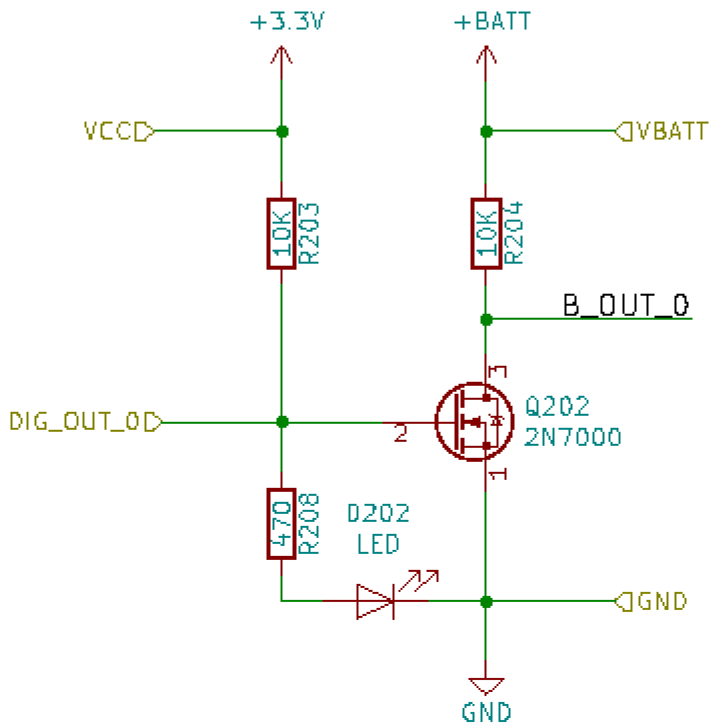

Figure 6 Typical Digital Output

Configuring PUTSI

Configuring for USB mode only

The device is preconfigured to work in the USB mode with the Wi-Fi disabled. No further configuration is required if this is the only mode of operation required. All setup parameters are ignored as the USB requires no further configuration.

Configuring for WiFi mode

If the WiFi mode is to be used, either in lieu of the USB or in tandem with it, it has to be configured before it can be used. To enter the configuration mode, insert a jumper into the 'CONF' pins close to the processor, and toggle the reset switch. It will come up with the COM led flashing Red.

The Wi-Fi setup page can be launched by connecting to the network 'PUTSI Wi-Fi', using a PC, smart phone or tablet; there is no password needed. Launch a web browser and go to address 192.168.36.1, the device will respond with the configuration page as shown in Figure 7.

All parameters for the server IP, Radio ID, Network name and password must be entered with the correct information.

Dual mode

The device can operate in both modes simultaneously, but this has to be configured using the Wi-Fi setup page.

WIFI Setup Page

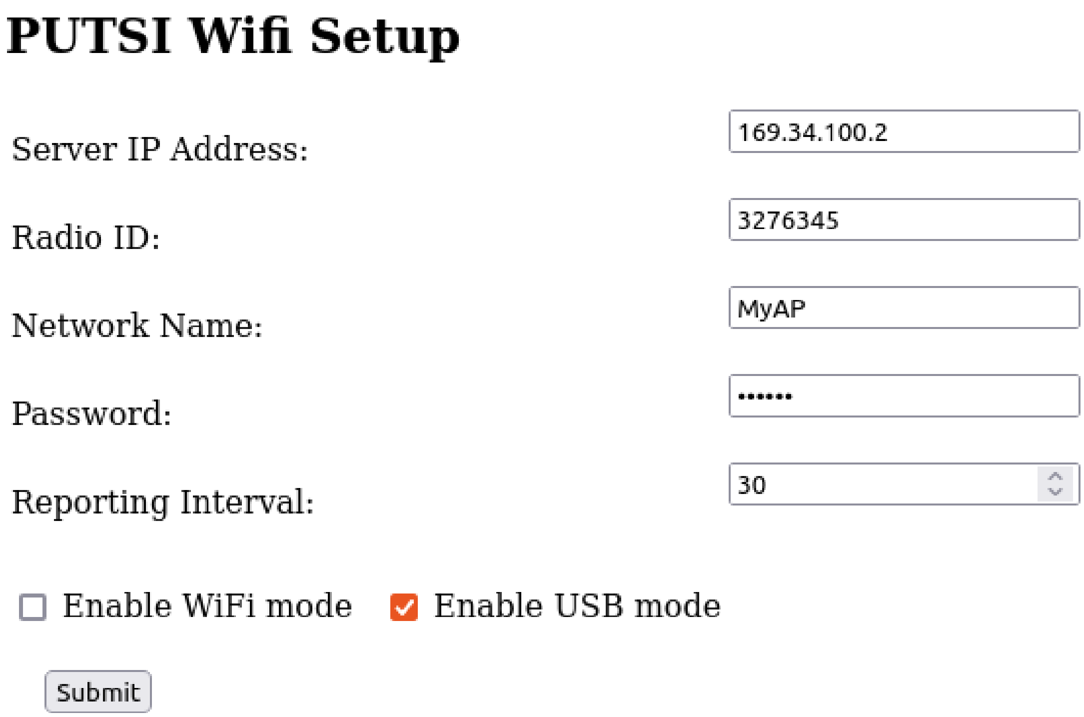

Figure 7 Wi-Fi Configuration Page

The settings are illustrated in Table 8.

Setting	Contents
Server IP Address	IP address of the telemetry server on the network for WiFi mode
Radio ID	Unique radio ID, up to 7 characters
Network Name	Name of the network where to connect (Access point)
Password	Network password
Reporting Interval	Interval between reports in seconds; recommended value is 30.
Enable WiFi Mode	Enables the transmission of packets over WiFi
Enable USB Mode	Enables the USB mode

Table 8 Wi-Fi Configuration settings

Configuring Allstar

There are four configuration entries that need to be considered, all of which are entered into the rpt.conf configuration file in /etc/asterisk. After configuration, the analog inputs can be calibrated.

1. Enter the base setup so that Allstar can find the device and know how the pins are mapped. This cannot be changed as it is fixed in PUTSI, however the configuration data is processed.
2. Enter the [meter-faces] section to correctly interpret the analog inputs.
3. Enter alarm conditions to process digital inputs.
4. Enter functions to respond to alarms and set outputs.

Base configuration

The base configuration lists all the data acquisition devices, (usually one), their hardware type and to which physical port they are connected. Following that is the pin definitions.

```
; Data Acquisition configuration
[daq-list]
device = daq-putsi

[daq-putsi]                 ; Defined in [daq-list]
hwtype = uchameleon         ; DAQ hardware type (fixed in app-rpt)
devnode = /dev/ttyACM0      ; DAQ device node
(pins go in here…)
```

Pin Definitions

Allstar maps the 8 analog inputs, 5 digital inputs and 5 digital outputs to a series of 18 contiguous pins, starting at Pin 1. The Allstar pin to actual input or output are shown in Table 9.

Allstar Pins	Type	Physical Input
1-8	inadc	Analog channels 1-8
9-13	inp	Inputs 1-5
14-18	out	Outputs 1-5

Table 9 Allstar pin mapping

All functions must reference the pin by the Allstar pin number.

The pin definitions are fixed and must be entered as shown below.

```
1 = inadc                    ; Pin definition for an ADC channel
2 = inadc
3 = inadc
4 = inadc
5 = inadc
6 = inadc
7 = inadc
8 = inadc
9 = inp                      ; Pin definition for an input
10 = inp
11 = inp
12 = inp
13 = inp
14 = out                     ; Pin definition for an output
15 = out
16 = out
17 = out
18 = out
```

Figure 8 Basic Setup

Meters

Meters translate the reading from the A/D converter into useful units such as voltage, temperature, wind speed, etc. The declarations are in the [meter-faces] stanza, which takes three parameters, a scale function, which words to say, and the calculated value. There are three parameters to the scale function, as below:

1. An offset to be added first.
2. Scale divider, full scale reading/number of whole units, division occurs second.
3. A post offset added after the division.

The words represent word files in /var/lib/asterisk/sounds, and its sub-directories. The first part is implied, the remainder of the path must be entered. The extension can be omitted.

The result of the scale function is represented by a question mark (?) as a parameter in the command.

The syntax of the meter face command is:

```
facename = scale(scalepre,scalediv,scalepost),word/?,...
```


For the battery voltage, an example syntax would be:

```
[meter-faces]
batvolts = scale(0,16.71,0),rpt/thevoltageis,?,ha/volts
```

Figure 9 Sample Meter Face for battery voltage

Where the scalar is 16.71, the default value as shown in Table 7.The words 'thevoltageis' and 'volts' exist in sub-directories of the *sounds* main directory.

Alarms

Alarms monitor input pins and execute functions based on their change of state. The declarations are made in the [alarms] stanza, which takes 7 parameters, as listed in *Table 10*.

Parameter	Purpose
name	A unique tag identifying the alarm
device	Set to [daq-putsi]
pin	Pin number to monitor, as defined in Figure 8.
ignorefirstalarm	set to 1 to throwaway first alarm event, or 0 to report it
node	the node number where the function are defined
func-lo	the function to execute on a high to low transition
func-high	the function to execute on a low to high transition

Table 10 Allstar alarm parameters

The syntax to generate an alarm from a door switch attached to the first input (Pin 9), and to monitor an AC power failure is as follows:

```
[alarms]
doorpic = daq-putsi,9,0,(your node number),*852,*851
pwrfailpic = daq-putsi,10,0,(node),*862,*861
```

Figure 10 Sample Alarm statement

When the door is opened, function 851 is executed, when closed, 852. These are explained in the Functions section.

Controlling Outputs

The digital outputs are controlled by the 'userout' function, the declarations are in the [functions] stanza. It takes four parameters:

Parameter	Purpose
Device	Device to control, set to 'daq-putsi'
Pin Number	Output pin number as defined in Figure 8.
State	1 to turn on, 0 to turn off
Playback	File to playback for an audio response

Table 11 Output function definition

An example of a function to turn on the first output is:

```
userout,daq-putsi,14,1,rpt/on
```

Functions

Functions entry into generating telemetry messages as well as controlling digital outputs. There are quite a large number of functions that are already defined; however it was discovered that any value starting with 82 through 89 were unused. The functions can be configured as shown in Table 12. The generic form of a function is:

```
[functions]
(DTMF Code)=[Statement]
```

DTMF Code	Statement	Function
841	meter,daq-putsi,1,batvolts	Invokes the meter-face as shown in Figure 9 to announce the battery voltage
851	playback,ha/dooropen	Announces that the door is opened in response to an alarm on Pin 9.
852	playback,ha/doorclosed	Announces that the door has been closed.
861	playback,ha/dcoff	Announces that the AC power is off
862	playback,ha/dcon	Announces that the AC power has been restored
870	userout,daq-putsi,14,1,rpt/on	Turns on Pin 14 (output 1) and announces it
871	userout,daq-putsi,14,0,rpt/off	Turns off Pin 14 (output 1)
872-877	**(repeated for pins 15-18)**	
878	userout,daq-putsi,18,1,rpt/on	Turns on Pin 18 (output 5)
879	userout,daq-putsi,18,0,rpt/on	Turns off Pin 18 (Output 5)

Table 12 Function definitions

Calibration

Due to component tolerances, the actual voltage returned may not be exact. To calibrate it, start with the recommended scalar values, then a calibrated value can be calculated. Connect a voltage source to the battery input, preferably at 10.0V as it makes the calculation easy. If that is not available, then measure the voltage at the input terminals.

Start Allstar and wait for it to stabilize and execute the DTMF function (see Table 12) to announce the voltage reading. A new calibration factor can be calculated from the voltage reading using the formula:

$$New\ Scalar = \frac{Scalar\ x\ Reading}{Input\ Voltage}$$

The meter faces scalar can be updated with the new scalar value, then restart asterisk to accept the new values.

Operation

USB Mode

The USB interface provides a popular connection to most devices. It follows the protocol of the USB chameleon device that was initially supported by AllStarLink. All data is sent as ASCII characters and is terminated with a line feed ($0A_{16}$) character.

There are three phases of communication:

1. Handshake
2. Configuration
3. Data Exchange

The handshake mode is entered after powering up and when the reset button is depressed. The COM LED is off until the handshake has been completed. The device waits for a message from the host to send an identification string, and, if recognized, the host then sends a command to activate the COM led, which be on a solid RED when the connection has been established. A response is sent to the host at least once every 50ms to maintain the connection. If no data has been solicited or is ready to be sent, an empty line is sent to maintain the connection.

There are two types of data exchanges, host originated and asynchronous. The host originated mode is used to solicit data from the analog channels as well as changing the digital outputs. When the hosts wants to get an update from the analog inputs, it sends the channel number and type information, and the device responds with the current reading, in the range of 00_{16}-FF_{16}.

For digital outputs, the channel number and state are sent in the message, no response is sent. A change in a digital input results in a message being sent asynchronously to the host with no solicitation.

Asterisk (Allstar) only performs the handshake and configuration once after it has been restarted. If the communication fails, the USB mode will be disabled after 2 seconds of inactivity and the COM Led turned off. To restart it requires that asterisk also be restarted. From the console, as a super-user, it can be accomplished with the command:

```
# service asterisk restart
```

WiFi Mode

Once the client data has been configured and, if inserted, the CONF jumper is removed, the reset key is depressed to restart the device. If a connection to the network is successful, the COM led is set to a steady GREEN. The ACT led shows when data traffic is being over the wireless connection.

Periodic updates are sent to the monitoring server based on the interval specified on the configuration page, the inputs and outputs are only scanned once during this interval, responses to a digital output command can be delayed by this time as well.

If both modes are enabled, then the COM Led will alternately flash red and green when BOTH connections are established.

COM Led

The COM Led is a bicolour LED that can be red or green, depending on the operational mode. The LED can either be on or flashing, as illustrated in Table 13.

Color	Mode	Meaning
NONE	Off	No communication mode is currently active.
RED	Flashing	Configuration mode has been entered; AP is active.
RED	Steady	A connection has been made to a WiFi access point; the USB mode has not completed a handshake.
GREEN	Steady	The USB is connected to a host computer and the handshake is compete. No Wifi Connection has been made.
RED/GREEN	Flashing	Both USB and WiFi modes are operational.

Table 13 COM Led modes

WiFi Telemetry Packet Specification

Telemetry packets use the USRP protocol format and are sent using the User Datagram Protocol (UDP) for its transport, which is connectionless. Each packet consists of several fields as illustrated below:

USRP Header 32 Bytes	TLV Header 3 Bytes	Payload Data Up to 255 bytes

Table 14 Telemetry packet format

USRP header

The packet header fields are shown in Table 15.

Field Name	Size (Bytes)	Type	Value	Usage for Telemetry
Eye	4	byte	'USRP' in ASCII	Required
Sequence	4	unsigned integer	Sequencer counter	Incremented by one
Memory	4		Memory ID or zero	Ignored
Keyup	4		1 to indicate transmitter keyed, 0 otherwise	
Talkgroup ID	4		ID of the current talkgroup	
Type	4		Packet type, see Table 16	only TLV used for telemetry
MPXID	4		Multiplex ID	ignored
Reserved	4		Reserved for future use	

Table 15 USRP Header fields

There are 7 defined packet payload types, all telemetry packets are TLV packets. The others are listed purely for documentation purposes.

Packet Type	Definition	Contents
0	Voice	Voice coded as 16-bit linear PCM in little endian format
1	DTMF	DTMF coded as per RFC4733
2	TEXT	Text message
3	PING	Ping message
4	TLV	Type-Length-Value packet
5	ADPCM	Voice coded as adaptive delta pulse code modulation
6	ULAW	Voice coded using G711 µLaw

Table 16 USRP packet types

TLV Header

The TLV header is defined in Table 17.

Byte	Size	Content
1	8-bit unsigned integer	Type field
2		Length of entire payload (including TLV header)
3		Value field, up to 255 bytes

Table 17 TLV packet header

There are 13 different types of TLV payload types as illustrated in Table 18, all telemetry packets use a type 12, the others are listed for documentation purposes.

Type	Payload
0	Begin transmit tag
1	AMBE coded voice packet
2	End transmit tag
3	Tune
4	Play AMBE packet
5	Remote Command
6	AMBE_49
7	AMBE_72
8	Information packet
9	IMBE
10	DSAMBE
11	File transfer
12	Telemetry

Table 18 TLV packet types

The telemetry system uses a type 12 packet.

Payload Data

The payload data contains a radio ID, and a series of data fields, up to the maximum data field size, as shown in Table 19.

Radio ID	Data Field 1	Data Field 2	Data Field n

Table 19 Payload Data fields

Data fields contain three different entries as illustrated in Table 20

Entry	Size (bytes)	Contents
Entry type	1	Identifies the entry type
Number of Entries	1	Number of entries in the field
Field Data	1-2	Field data in big endian format

Table 20 Information packet fields

There are three entry types as shown in Table 21:

Type	Size (bytes)	Data type
0	2	Analog input reading
1	1	Digital inputs, zero=off, non-zero=on
2	1	Digital outputs

Table 21 Entry types

Packet Exchange

The frequency of packets is up to the telemetry device to determine. At the receiver the database is updated immediately, the display is dynamically updated each time a new record is written to the database.

The uploaded packet must contain all field types, all fields must reflect the current state of all inputs and outputs. A response packet is sent back immediately, and if the device supports digital outputs this field will be included, otherwise the payload field will be empty. The response packet will contain the same sequence number in the header as the uploaded packet, so this field can be used by the telemetry device as an implicit acknowledgement.

If no response is heard, then it can be assumed that the link is down, and the packet was not received. The recovery procedure is up to the specific device. It is recommended that local statistics be kept for this purpose.

PUTSI™ WiFi Application Notes

AN001: Measuring Temperature

Written by:
Martin Alcock, M. Sc, VE6VH

For Software Revision: 0.2a

Alberta Digital Radio Communications Society,
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Document Revision History

Date	Rev	Description
Sept, 2023	0.2a	Initial draft, companion to rev 0.2a manual

Table 1 Revision History

Reference Documents

[1] gnu.org, "General Public Licence," [Online]. Available: https://www.gnu.org/licenses/gpl-3.0.en.html. [Accessed 25th February 2018].

[2] Analog Devices Inc, "Low Voltage Temperature Sensors," [Online]. Available: https://www.analog.com/media/en/technical-documentation/data-sheets/TMP35_36_37.pdf. [Accessed 20 09 2023].

[3] Texas Instruments, "TMP61," [Online]. Available: https://www.ti.com/product/TMP61. [Accessed 20 09 2023].

Glossary of Terms

PBX	Private Branch Exchange. A node in a telephone network that provides connectivity for a series of local extensions to a set of trunks.
VOIP	Voice over Internet Protocol. A system where telephone calls are placed, and audio is exchanged using the Internet Protocol.
PUTSI	PIC USB Telemetry System Interface
Wi-Fi	Wireless Fidelity implementing the IEEE 802.11x standards.

Intellectual Property Notice

Disclaimer

This document is a preliminary release for a product still in development and may be subject to change in future revisions. The software may be subject to unpredictable behaviour without notice. You are advised to keep a can of RAID™ Ant, Roach and Program Bug killer handy. Spray liberally on the affected area when needed.

Introduction

Measuring temperature is an important part of determining the health of a repeater system. Critical temperatures such as the heat sink on the power amplifier, shack internal temperatures can easily be measured with the PUTSI device using one of two types of devices, a thermistor or active temperature probe.

A thermistor type temperature probe is a passive device that acts as a resistor which varies over temperature. These devices can be connected directly to PUTSI using one of the three configurable inputs, without any external components.

An active temperature probe is a solid state device that has an internal reference and provides a voltage output based on external temperature. These devices require a power supply and can be connected to any one of the analog inputs, including the configurable inputs.

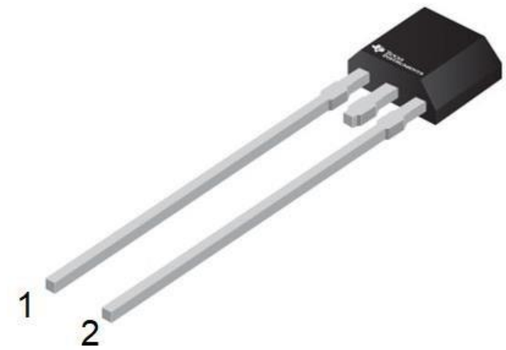
Table 2 illustrates the types and number that can be utilized:

Device Type	Connection	Max per System
Thermistor	Configurable inputs only	3
Active probe	Any analog input	7

Table 2 Probe types

Using a Thermistor

The recommended device is a TMP61 from Texas Instruments [2], which retails for around $1. Connect pin 2 to the regulated supply voltage of 3.3v (available at J301-4), and pin 1 to one of the configurable inputs on J401 or J402.



Pin Functions

PIN		TYPE	DESCRIPTION
NAME	NO.		
–	1	—	Thermistor (–) and (+) terminals. For proper operation, ensure a positive bias where the + terminal is at a higher voltage potential than the – terminal.
+	2		

Figure 1 TMP6131LPGM Leaded Thermistor Device

To measure power amplifier temperature the device can be mounted on a heat sink to measure or placed anywhere in the shack to measure the ambient temperature. The leads should be made of 24AWG wire, the length is not a factor as the resistance is minimal, however a length of under 10’ (3m) is recommended.

Configuring the Input

For a thermistor application, the jumper is connected to VCC (pins 2-3), the series resistor is jumpered, and pin is connected between an input and ground. RG is set to 10KΩ. A 1% tolerance resistor is recommended for better temperature accuracy, and to match the accuracy of the device. A maximum of three (3) devices can be supported.

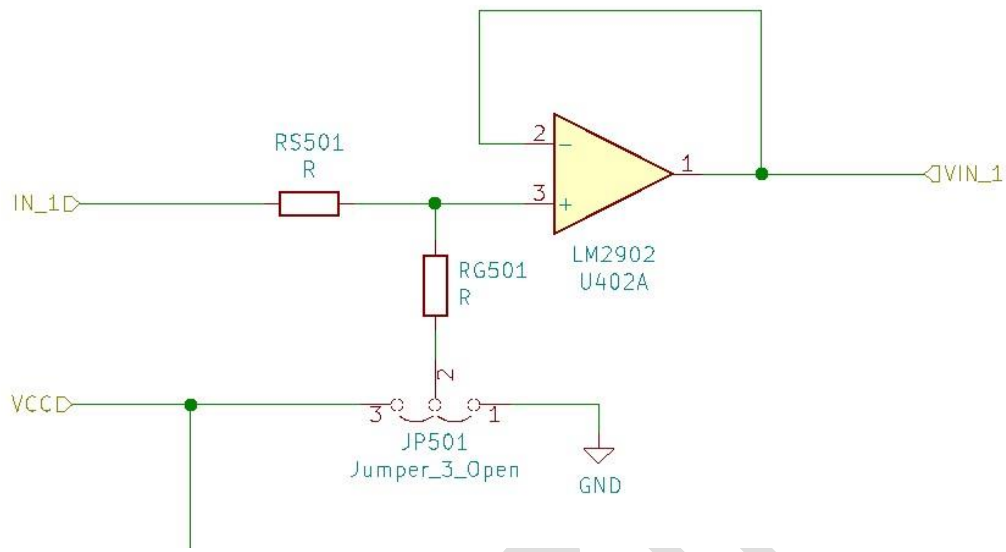


Figure 2 Configurable analog Input

Measurement

Table 3 illustrates the voltage inputs and A/D readings for the TMP61.

Temp (°C)	Temp (°F)	Res (Ω)	A/D Input	USRP Value	Allstar Value
-40	-40	6587	1.31	406	101
-25	-13	7265	1.39	430	107
-15	5	7750	1.44	447	111
0	32	8527	1.52	471	117
15	59	9368	1.60	495	123
25	77	9966	1.65	511	127
40	104	10920	1.72	534	133
65	149	12676	1.84	572	143
80	176	13832	1.92	594	148
100	212	15502	2.01	622	155

Table 3 A/D Voltage inputs and reading for TMP61

Configuring Allstar

Operating with Allstar requires that an entry is added to the meter faces stanza in the configuration file, and a function entry. For more information, consult the PUTSI manual document. The examples below illustrate entries for degrees Centigrade and Fahrenheit.

```
[meter-faces]
tempdegC = scale(-101,0.4,-40),rpt/thetemperatureis,?
tempdegF = scale(-117,0.222,32),rpt/thetemperatureis,?
```

Table 4 illustrates the expected readings from Allstar in degrees C based on the abbreviated word size and scaling factors shown above. Note that it is reasonably accurate from -40 to +65, but at higher temperatures it becomes non-linear.

Temp (°C)	Reading	Prescaler	Scalar	Postscaler	Temperature
-40	101	-101	0.4	-40	-40
-25	107				-25
-15	111				-15
0	117				0
15	123				15
25	127				25
40	133				40
65	143				65
80	148				78
100	155				95

Table 4 Allstar Readings in Degrees C

Table 5 illustrates the expected readings from Allstar in degrees Fahrenheit. The same non-linearity can be noticed above 150 degrees.

Temp (°F)	Reading	Prescaler	Scalar	Postscaler	Temperature
-40	101	-117	0.2222	32	-40
-13	107				-13
5	111				5
32	117				32
59	123				59
77	127				77
104	133				104
149	143				149
176	148				172
212	155				203

Table 5 Allstar Readings in Degrees F

USRP Telemetry

In the USRP (WIFI) mode, the readings are four times those in Allstar, as the full word size is utilized. The scaling factors are changed, as illustrated in Table 6 and Table 7. The non-linearities become more apparent earlier due to the wider word size.

Temp (°C)	Reading	Prescaler	Scalar	PostScalar	Temperature
-40	406	-406	1.625	-40	-40
-25	430				-25
-15	447				-15
0	471				0
15	495				15
25	511				25
40	534				39
65	572				62
80	594				76
100	622				93

Table 6 USRP Readings in Degrees C

Temp (°C)	Reading	Prescaler	Scalar	PostScalar	Temperature
-40	406	-471	0.902777	32	-40
-13	430				-13
5	447				5
32	471				32
59	495				59
77	511				76
104	534				102
149	572				144
176	594				168
212	622				199

Table 7 USRP Readings in Degrees F

Calibration

The scalar has been calculated based on the device resistance as specified by the manufacturer so it will not need to be adjusted. The prescaler value is the expected reading at the temperature specified in the postscaler, which is -40 in degrees C and 32 in degrees Fahrenheit.

The simplest adjustment can be made by altering the postscalar value until it reads accurately. Adjusting by ±1 will adjust the calculated temperature according, in the relevant scale. The accuracy is within ±1 degree in the linear range.

Using an Active Device

The recommended active device for temperature measurement is the TMP36 [3] from Analog Devices, which retails for about $3. Connect pin 1 to the regulated supply voltage of 3.3v (available at J301-4), pin 2 to a configurable input and pin 3 to ground.

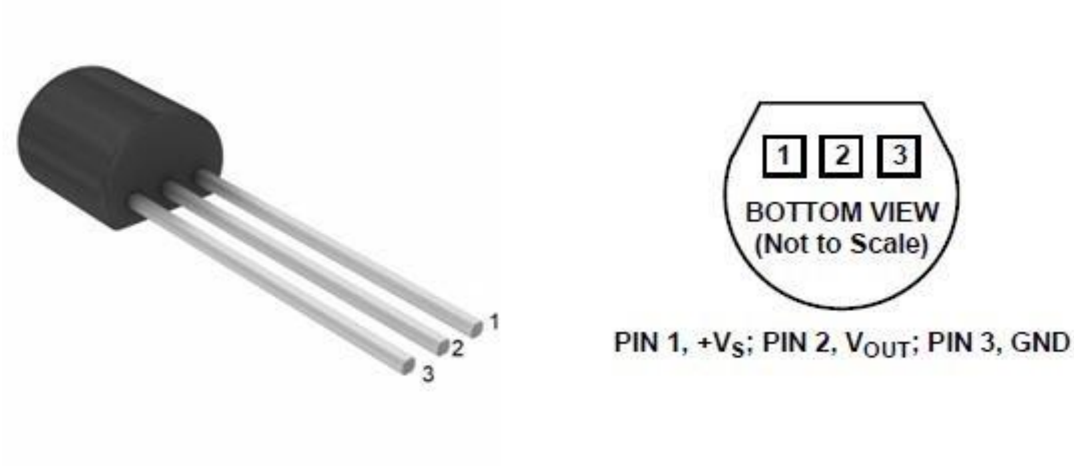


Figure 3 Analog Devices TMP36 in a TO-92 package

As the device sources a voltage, any length of wire can be used, however it is recommended to keep it to less than 25’ in order to maintain the correct power supply voltage for 24AWG. However, for longer lengths a larger wire gauge is recommended.

Configuring the Input

Figure 4 illustrates one if the 4 non-configurable analog inputs. Two resistors are used to implement a voltage divider, Rs and Rg. A configurable input by inserting the jumper to ground (pins 1-2), in which case it has the identical circuit. Any one of the 7 inputs can be used.

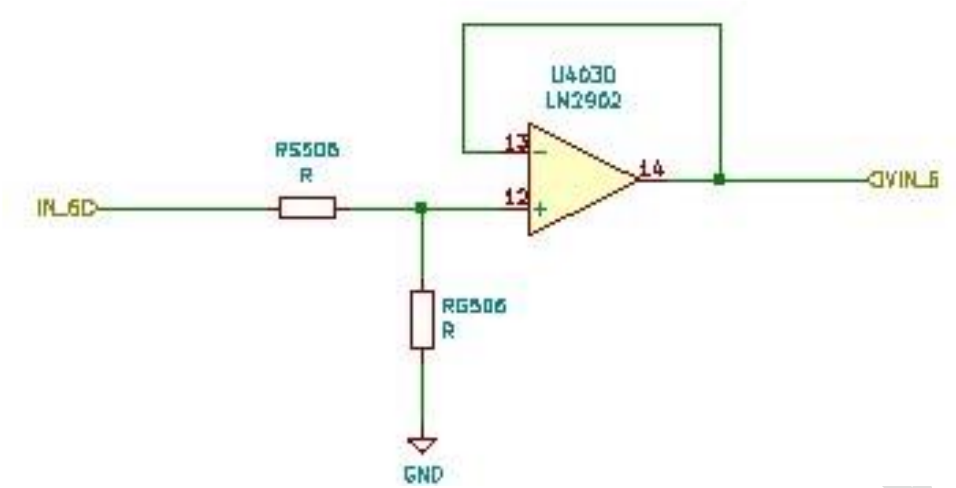


Figure 4 Analog Input Circuit

For both degrees Centigrade and Fahrenheit, the output voltage is within the A/D input limits, so Rs can be jumpered with a wire, and Rg omitted.

Measurement

Table 8 illustrates the voltage inputs and A/D readings for the TMP36.

Temp (°C)	Temp (°F)	A/D Input	USRP	Allstar
-40	-40	0.1	31	7
-25	-13	0.25	77	19
-15	5	0.35	108	27
0	32	0.5	155	38
15	59	0.35	108	27
25	77	0.75	232	58
40	104	0.9	279	69
65	149	1.15	356	89
80	176	1.3	403	100
100	212	1.5	465	116

Table 8 A/D Voltage inputs and reading for TMP36

Configuring Allstar

Operating with Allstar requires that an entry is added to the meter faces stanza in the configuration file, and a function entry. For more information, consult the PUTSI manual document. The examples below illustrate entries for degrees Centigrade and Fahrenheit.

```
[meter-faces]
tempdegC = scale(-7,0.8,-40),rpt/thetemperatureis,?
tempdegF = scale(-8,0.4444,30),rpt/thetemperatureis,?
```

Table 9 illustrates the expected readings from Allstar in degrees C based on the abbreviated word size and scaling factors shown above.

Temperature	Voltage	A/D Count	Prescaler	Scalar	PostScaler	Scaled
-40	0.1	7	-7	0.8	-40	-40
-25	0.25	19				-26
-15	0.35	27				-16
0	0.5	38				-2
15	0.65	27				13
25	0.75	58				23
40	0.9	69				37
65	1.15	89				62
80	1.3	100				76
100	1.5	116				96

Table 9 Measuring Temperature in deg C using TMP36

Table 10 illustrates the expected readings from Allstar in degrees F.

Temperature	Voltage	A/D Count	Prescaler	Scalar	PostScaler	Scaled
-40	0.1	7	-38	0.4444	30	-40
-13	0.25	19				-13
5	0.35	27				5
32	0.5	38				30
59	0.65	27				57
77	0.75	58				75
104	0.9	69				99
149	1.15	89				144
176	1.3	100				169
212	1.5	116				205

Table 10 Measuring Temperature in deg F using TMP36

USRP Telemetry

In the USRP (WIFI) mode, the readings are four times those in Allstar, as the full word size is utilized. The scaling factors are changed, as illustrated in Table 11 and Table 12. The non-linearities become more apparent earlier due to the wider word size.

Temp (°C)	Reading	Prescaler	Scalar	PostScalar	Temperature
-40	31	-31	3.2	-40	-40
-25	77				-26
-15	108				-16
0	155				-1
15	201				13
25	232				23
40	279				38
65	356				62
80	403				76
100	465				96

Table 11 USRP Readings in Degrees C

Temp (°C)	Reading	Prescaler	Scalar	PostScalar	Temperature
-40	31	-31	1.7	-40	-40
-13	77				-13
5	108				5
32	155				32
59	201				59
77	232				76
104	279				102
149	356				144
176	403				168
212	465				199

Table 12 USRP Readings in Degrees F

Calibration

The scalar has been calculated based on the device resistance as specified by the manufacturer so it will not need to be adjusted. The prescaler value is the expected reading at the temperature specified in the postscaler, which is -40 in both scales.

The simplest adjustment can be made by altering the postscalar value until it reads accurately. Adjusting by ±1 will adjust the calculated temperature according, in the relevant scale. The accuracy in the linear range is with ±2 degrees.

ADRCS

Alberta Digital Radio Communications Society

PUTSI™ WiFi Application Notes

AN002: Measuring PA Current

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For Software Revision: 0.2a

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Sept, 2023	0.2a	Initial draft, companion to rev 0.2a manual

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Distribution

Rev	Distribution
All	For amateur use only.

Table 2 Distribution

Reference Documents

[1] gnu.org, "General Public Licence," [Online]. Available: https://www.gnu.org/licenses/gpl-3.0.en.html. [Accessed 25th February 2018].

[2] Analog Devices Inc, "Low Voltage Temperature Sensors," [Online]. Available: https://www.analog.com/media/en/technical-documentation/data-sheets/TMP35_36_37.pdf. [Accessed 20 09 2023].

[3] Texas Instruments, "TMP61," [Online]. Available: https://www.ti.com/product/TMP61. [Accessed 20 09 2023].

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Wi-Fi	Wireless Fidelity implementing the IEEE 802.11x standards.

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Introduction

Measuring PA current requires an external circuit to first sense the current and then convert it to an analog voltage in the range of 0-3.3V.

The recommended device is an ACS770LCB-050U from Allegro Microsystems. It has as self-contained shunt and differential amplifier, and retails for around $15. The suffix is important as it determines the output voltage from the device. It can handle currents up to 50A. An external circuit board has been developed to accommodate the device, which only requires connection to the power leads of the amplifier and to a voltage input.

X050U PERFORMANCE CHARACTERISTICS [1]: T_{OP} = –40°C to 150°C, C_{BYP} = 0.1 µF, V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Primary Sampled Current	I_P		0	–	50	A
Sensitivity [2]	$Sens_{TA}$	Measured using full-scale I_P, T_A = 25°C	78.08	80	81.92	mV/A
	$Sens_{(TOP)HT}$	Measured using full-scale I_P, T_{OP} = 25°C to 150°C	78.08	80	81.92	mV/A
	$Sens_{(TOP)LT}$	Measured using full-scale I_P, T_{OP} = –40°C to 25°C	77.2	80	82.8	mV/A
Sensitivity Drift Over Lifetime [3]	$\Delta Sens_{LIFE}$	T_{OP} = –40°C to 150°C, shift after AEC-Q100 grade 0 qualification testing	–1.44	±0.48	1.44	mV/A
Noise [4]	V_{NOISE}	T_A= 25°C, 10 nF on VIOUT pin to GND	–	20	–	mV
Nonlinearity	E_{LIN}	Measured using full-scale and half-scale I_P	–1	–	1	%
Electrical Offset Voltage [5][6]	$V_{OE(TA)}$	I_P = 0 A, T_A = 25°C	–10	±4	10	mV
	$V_{OE(TOP)HT}$	I_P = 0 A, T_{OP} = 25°C to 150°C	–10	±6	10	mV
	$V_{OE(TOP)LT}$	I_P = 0 A, T_{OP} = –40°C to 25°C	–20	±6	20	mV
Electrical Offset Voltage Drift Over Lifetime [3]	$\Delta V_{OE(LIFE)}$	I_P = 0 A, T_{OP} = –40°C to 150°C, shift after AEC-Q100 grade 0 qualification testing	–5	±2	5	mV
Magnetic Offset Error	I_{ERROM}	I_P = 0 A, T_A = 25°C, after excursion of 50 A	–	120	300	mA
Total Output Error [7]	$E_{TOT(TA)}$	Measured using full-scale I_P, T_A = 25°C	–2.4	±0.5	2.4	%
	$E_{TOT(HT)}$	Measured using full-scale I_P, T_{OP} = 25°C to 150°C	–2.4	±1.5	2.4	%
	$E_{TOT(LT)}$	Measured using full-scale I_P, T_{OP} = –40°C to 25°C	–3.5	±2	3.5	%
Total Output Error Drift Over Lifetime [3]	$\Delta E_{TOT(LIFE)}$	T_{OP} = –40°C to 150°C, shift after AEC-Q100 grade 0 qualification testing	–1.9	±0.6	1.9	%

Figure 1 Allegro Microsystems ADC770 Hall Effect Sensor

Circuit Board

Figure 2 shows the schematic diagram of the current monitor. It contains the ACS770, a +5v regulator, and screw terminals for connection. No other external components are required.

The polarity of the ACS770 is important, as the device is designed for DC applications. The IP+ input must connect to the power supply, and the IP- to the downstream device. Reversing these connections may damage the device.

The maximum recommended current flow is 40A, to maintain the output voltage within range of the A/D converter.

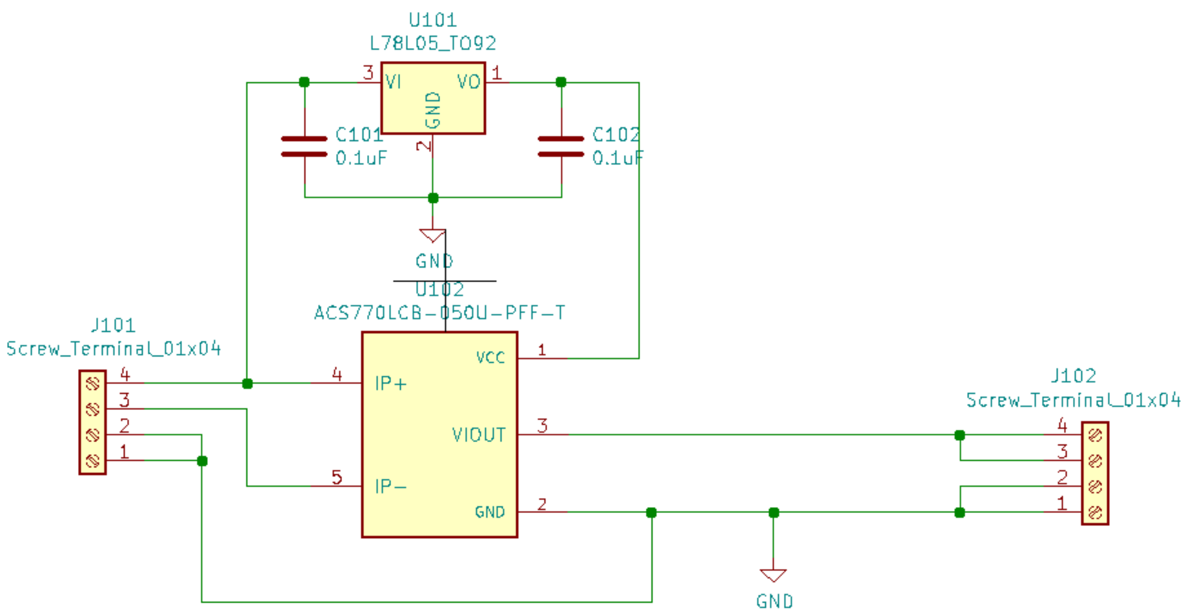

Figure 2 Current monitor Schematic diagram

Figure 3 illustrates the circuit board for the Allegro ACS770.

On the left side are the connections to the power supply and radio, and on the right side is the output voltage that can be connected to any analog input.

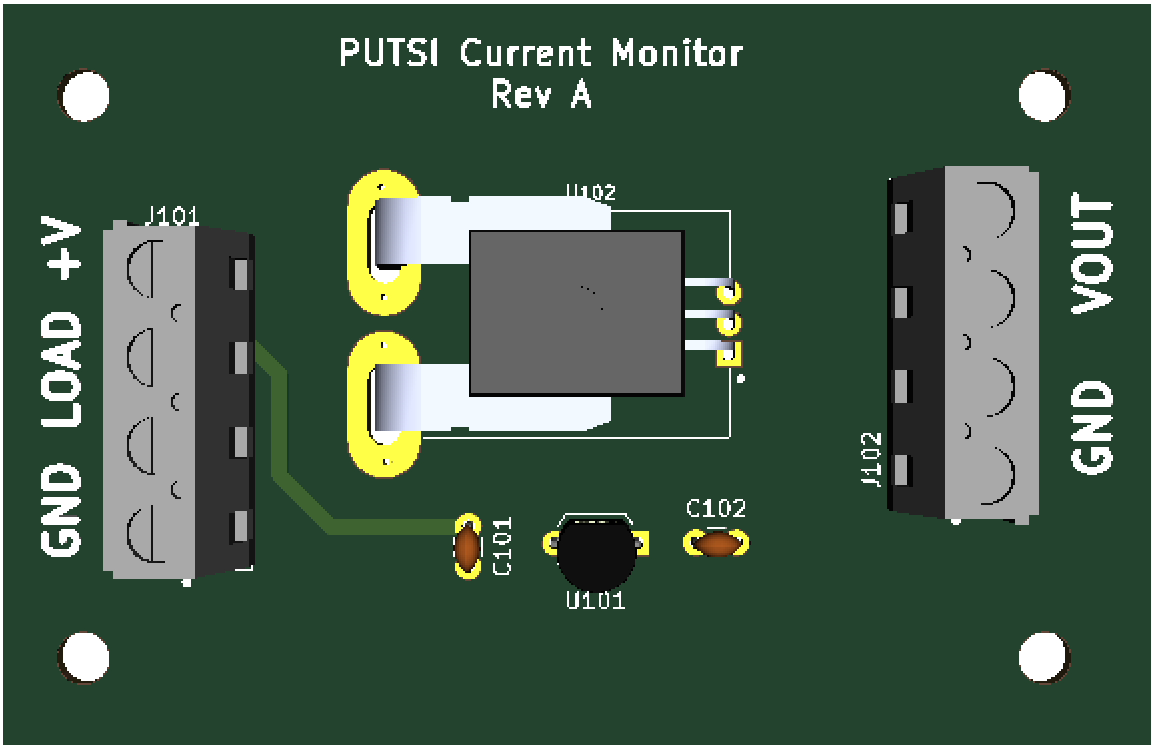

Figure 3 Current Monitor Circuit Board

Table 3 illustrates how the device should be connected in a repeater system.

Connections

Name	Location	Connect to
+V	J101-4	The positive of the power supply
LOAD	J101-3	The positive supply to the power amplifier
GND	J101-1,2	Connect to the power supply ground
VOUT	J102-3,4	Connect to an unused analog input
GND	J102-1,2	Connect to a ground on the telemetry board

Table 3 PCB Connections

Measurement

Table 4 shows the measurements that can be expected from various currents. The output of the ACS770 is 80mv/A, and each count of the A/D is approximately 3.2mV.

The USRP mode uses a 10 bit resolution, Allstar only uses 8, so the values read by allstar are ¼ of the USRP readings.

Current (A)	Voltage	USRP Reading	Allstar Reading
1	0.08	24	6
5	0.4	124	31
10	0.8	248	62
15	1.2	372	93
20	1.6	496	124
25	2	620	155
30	2.4	744	186
35	2.8	868	217
40[1]	3.2	992	248

Table 4 Expected readings from current flow

Configuring Allstar

Configuring Allstar requires a meter face entry to conver the A/D reading back into amps. Usign a divisor of 6.2 will convert the reading back to Amps.

```
[meter-faces]
paCurrent = scale(0,6.2,0),?,ha/amps
```

USRP configuration

In the USRP mode, the divisor becomes 24.8 (four times the Allstar value).

Calibration

No calibration is required.

[1] Recommended Maximum to stay within maximum A/D Input voltage range