THE KUMU A`O CUBE SATELLITE SHARE BOARD

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ABSTRACT

The Kumu A`o Cube Satellite will measure the temperature of its solar cell boards, its battery, and its transceiver using the thermal subsystem. With a tight volume budget inside the one unit cube measuring 1 cubic liter in volume, there is not enough space in the satellite to have an exclusive temperature monitoring board. Instead, structural, part of telecommunications, and the thermal subsystem will need to combine onto what is being called the share board that will consume only a single layer in the PC104 stack. For structure, the share board consists of nichrome wire burn circuits for antenna and gravity gradient boom deployment as well as antenna and boom deployment feedback. For thermal, all eight temperature measurements are acquired by thermistor voltage dividers whose outputs are digitized using a12-bit ADC. For the telecommunications portion, a ham transceiver, square wave filter for Morse tone generation, and a PTT control circuit are included. The circuit schematic for the share board has been completed and is explained with emphasis on the temperature monitoring circuit and square wave filter. The performance of the square wave low pass filter has been simulated using PSpice to ensure proper component values. Work to complete include PCB layout for the share board for manufacture and circuit board testing.

INTRODUCTION

At the University of Hawaii at Manoa, an undergraduate engineering team is developing a one unit cube satellite for launch in the near future. Meaning the source of learning in the Hawaiian language, If the launch is successfully, Kumu A`o will be the University of Hawaii’s first cube satellite to achieve low earth orbit. The mission of Kumu A`o is to provide proof of concept that UHM students are capable of taking a stand against other cube satellite teams from around the world. Unlike other teams, the University of Hawaii would become the world's first university to launch cube satellites along with a primary payload designed by the university as well.

To add to the value of Kumu A`o, the team has decided to include a few payloads, one of which is a temperature monitoring circuit. Unlike the thermal subsystems in larger satellites, Kumu A`o will not have radiation plates or heating foils to regulate its internal temperature. Instead, its thermal system will be entirely passive in that it will make use of self heating and multi-layered insulation (MLI) to protect itself against the temperature swings expected in low earth orbit (LEO). The temperature monitoring circuit will monitor the surface temperatures of all six solar cell panels on the outside of Kumu A`o and the temperature of the battery and transmitter.
PURPOSE OF THE SHARE BOARD

Due to the limited space onboard, the temperature monitoring circuit is located on a board that will contain circuits from structural and telecomm. Since three subsystems are sharing a single board, we naturally called this board the share board. This paper describes the design process for the entire share board with emphasis on developing the temperature monitoring circuit and Morse tone filter.

PC104 BUS AND THE SHARE BOARD

Like all of Kumu A`o’s printed circuit boards, the PC104 bus will be pass all the control signals, data lines, and most of the power lines to the share board. The only exceptions are wire harnesses for powering the VX3R and the connection between the TNC and the share board.

Table 1: Listing of all signals, data, and power lines provided to and from the share board.

<table>
<thead>
<tr>
<th>Header</th>
<th>Pin</th>
<th>Name</th>
<th>Type</th>
<th>Subsystem</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>10</td>
<td>STRUCT_ANTCTRL</td>
<td>Signal Out</td>
<td>Structural</td>
<td>Control signal for antenna deployment</td>
</tr>
<tr>
<td>H1</td>
<td>11</td>
<td>STRUCT_ANTFBCTL</td>
<td>Signal In</td>
<td>Structural</td>
<td>+3.3V control signal from FM430 for antenna feedback control</td>
</tr>
<tr>
<td>H1</td>
<td>12</td>
<td>STRUCT_ANTFB</td>
<td>Signal Out</td>
<td>Structural</td>
<td>Antenna feedback signal</td>
</tr>
<tr>
<td>H1</td>
<td>13</td>
<td>STRUCT_GBCTRL</td>
<td>High Power</td>
<td>Structural</td>
<td>9V power for nichrome wire burn</td>
</tr>
<tr>
<td>H2</td>
<td>14</td>
<td>TEL_PTT</td>
<td>Signal In</td>
<td>Telecom</td>
<td>+3.3V control signal from FM430 for PTT</td>
</tr>
<tr>
<td>H2</td>
<td>15</td>
<td>TEL_MUXCTL</td>
<td>Signal In</td>
<td>Telecom</td>
<td>Select signals for Morse or packet radio</td>
</tr>
<tr>
<td>H2</td>
<td>16</td>
<td>TEL_MICROPHONE</td>
<td>Signal In</td>
<td>Telecom</td>
<td>PWM Morse signal from FM430</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TONE_CTL</td>
<td>Signal In</td>
<td>Telecom</td>
<td>Controls Morse tones to microphone input.</td>
</tr>
<tr>
<td>H2</td>
<td>21</td>
<td>I2C_SDA</td>
<td>Signal Out</td>
<td>Thermal</td>
<td>Serial data to FM430 from ADC</td>
</tr>
<tr>
<td>H2</td>
<td>23</td>
<td>I2C_SCL</td>
<td>Signal In</td>
<td>Thermal</td>
<td>Serial clock from FM430 to ADC</td>
</tr>
<tr>
<td>H2</td>
<td>14</td>
<td>STRUCT_GBFBCTL</td>
<td>Signal In</td>
<td>Structural</td>
<td>+3.3V control signal from FM430 for gravity boom feedback control</td>
</tr>
<tr>
<td>H2</td>
<td>15</td>
<td>STRUCT_GBFB</td>
<td>Signal Out</td>
<td>Structural</td>
<td>Gravity boom deployment feedback</td>
</tr>
<tr>
<td>H2</td>
<td>24</td>
<td>TEMA_CTL</td>
<td>Signal In</td>
<td>Thermal</td>
<td>Thermal circuit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I2C_ENABLE</td>
<td>Signal In</td>
<td>Thermal</td>
<td>Enables and disables I2C repeater</td>
</tr>
<tr>
<td>H2</td>
<td>27</td>
<td>+3.3V</td>
<td>Power</td>
<td>All</td>
<td>Vcc</td>
</tr>
<tr>
<td>H2</td>
<td>30</td>
<td>0V</td>
<td>Ground</td>
<td>All</td>
<td>Analog and Digital Ground</td>
</tr>
<tr>
<td>Wire harness</td>
<td>-</td>
<td>+6V</td>
<td>High Current Power</td>
<td>Telecom</td>
<td>Power for the VX3R</td>
</tr>
</tbody>
</table>
The telecommunications circuit is composed of the transceiver, filter, and a multiplexer. The transceiver is the VX3R manufactured by Yaesu that is stripped of its casing.

**Connection to VX3R**

The VX3R will connect to the share board via a four-conductor wire harness containing on one end a four-conductor connector and on the other end a four-conductor miniature phone plug and a DC adaptor plug. The miniature phone plug will deliver the audio input to the radio from the share board and will transfer the audio output from the radio back to the share board. The DC adaptor plug delivers power to the VX3R.

**TNC Connector**

The TNC will connect to the share board via a three-conductor connector. The only signal going to the TNC will be audio out from the VX3R four-pin header. The other two signals are PTT out and audio out. The connection between these TNC outputs and the 2:1 mux is required for VX3R to TNC interfacing as specified by VX3R documentation [1].

**Low pass Filter**

The FM430 will generate a 1020Hz 3.3V 50% duty cycle square wave for Morse tones. This signal is named TEL_MICROPHONEROPHONE and arrives at the share board from the FM430 over the PC104 bus. This square wave is then sent through a filter to output a near sine wave to the 2:1 mux for the transmitter.

![Figure 1. Here is the two-pole low pass filter with DC block.](image)

**The Fourier Series of a Square Wave**

A Fourier transform of a 50% duty cycle square wave revealed that it is the sum of odd harmonic sine waves whose amplitude diminishes with frequency according to the following expression [2]:

$$ \frac{4k}{\pi} \left( \sin x + \frac{1}{3} \sin 3x + \frac{1}{5} \sin 5x + \ldots \right) $$

where k is the 3.3V for the square wave, x is \( \frac{2\pi f}{t} \) with \( f \) being the frequency of the square wave and \( t \) being time.

The only term in this series that has the same frequency as the square wave is the first term. All the following terms are odd harmonics of the fundamental frequency. Since the coefficients of x are increasing, the higher harmonics are the only frequencies that need to be filtered out to pass a sine wave at the fundamental frequency. This type of filter is also known as a low pass filter.
**Filter Requirements**

The low pass filter chosen is a passive two pole low pass filter. The requirements for the filter are to input a 3.3V 50% duty cycle square wave at 1020Hz and output a sine wave at 5mVpp at 1020Hz. In addition, the source impedance of the filter must also be 2kohm. These requirements were specified by the microphone input requirements for the VX3R [1]. The frequency of the sine wave was chosen to match the modulation frequency of aircraft Very High Frequency OmniRange (VOR) stations that transmit their Morse identifier at 1020 Hz [3].

**Filter Design**

The filter design is composed of three main elements: two cascaded RC filters, a DC block capacitor and an impedance set resistor.

The first step in the designing the filter was to determine the attenuation required to input a 3.3V square wave at 1020Hz and output a 5mVpp sine wave at the same frequency. A Bode plot representing the frequency response of the filter will be graph the gain of the filter in decibels (dB) with respect to frequency. The attenuation when comparing voltage levels is

\[ G_{dB} = 20 \log_{10} \frac{V_2}{V_1} \]  

(Eq. 1)

where \( G_{dB} \) is the gain for the filter in dB, \( V_2 \) is the peak to peak voltage after attenuation, and \( V_1 \) is the peak to peak voltage before attenuation.

\( V_2 \) is 5mVpp per the filter requirements. However, the value for \( V_1 \) is not quite as obvious. By examining Ex. 1, the amplitude voltage of the fundamental sine wave is \( \frac{4V}{\pi} \). This means that if the filter has unity gain (0dB), then the sine wave would have a peak to peak voltage of about 4.20V. The filter is really attenuating the sum of many sine waves with the fundamental sine wave having the greatest amplitude. So this is the voltage for \( V_1 \). By calculating the gain for the filter using Eq. 1, the result is about -58.489dB attenuation required. To obtain this, the filter was tuned by modifying the values for the resistor and capacitor in each RC filter until the Bode plot indicated about -58.489dB at 1020Hz.

**The DC block**

To remove the DC components of the square wave from the output signal, a high pass filter was placed in series with the low pass filter. The capacitor was chosen to be as small to reduce the time required for the capacitor to reach steady state. The resistor was chosen to provide 2kohm source impedance for the VX3R microphone input.

An AC sweep was performed on the circuit on the filter to arrive with the following Bode plot.
Figure 2. At approximately 1020 Hz, the filter’s gain is about -58dB.

To verify the steady state output of the filter, a transient simulation was performed in PSpice. The input was a 3.3V pulse that repeated forever at 1020Hz. To set this up, the user defines the square wave's rise time, fall time, pulse width, period, on voltage, and off voltage. As long as the rise and fall time for the repeating pulse is small compared to the pulse width, the input will be a square wave. The rise and fall times were both 1ms, period was 980.392us and the pulse width was at half that (50% duty cycle) at 490.196us. The on and off voltages were 3.3V and 0V respectively. The sine wave is not traced smoothly because PSpice did not choose a small enough time resolution. Nevertheless, Fig 3 confirms that the calculations were correct and the filter succeeds at attenuating a 3.3V square wave to approximately a 5mVpp sine wave at 1020Hz.

Figure 3. At less than a second after t=0, the filter output is approximately a sine wave with a period of 1020Hz and about 5mVpp.

**Morse PTT control**

During packet transmission from the TNC, the TNC controls the PTT signal for transmission. However, to transmit Morse tones to the ground station, the PTT will be controlled by the FM430. To do this the same PTT control circuit for the TNC was duplicated on the share
board and used as the PTT control circuit for transmitting the Morse tone [4]. The Morse PTT control circuit is composed primarily of a low pass filter whose input is connected to the FM430 GPIO and output connects to a MPS2222A NPN transistor. This transistor grounds the transceiver’s PTT signal when the GPIO pin is in a high state.

![Figure 4. The PTT Control Circuit.](image)

**SPDT Analog Switch**

Since both Morse tones and packet data will be transmitted to the ground station via the microphone input, the microphone input for the radio is switched to receive its input signal from either the TNC or the Morse tone low pass filter. The switch chosen for this is a single-pole double-throw (SPDT) analog switch, the TS5A3159, manufactured by Texas Instruments.

<table>
<thead>
<tr>
<th>IN</th>
<th>NC to COM (Morse to mic)</th>
<th>NO to COM (TNC to mic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td>H</td>
<td>OFF</td>
<td>ON</td>
</tr>
</tbody>
</table>

Table 2. Function table for the TS5A3159 analog switch.
The nichrome wire burn and deployment circuits for both the antenna and gravity boom deployment is also on the share board. A detailed description of these circuits and their function are given in the progress report of Mr. Jeremy Chan, CDH. So only a very brief description will be given here.

Both nichrome wire burn circuits are identical. Each circuit consists of an IRL540 N-channel MOSFET, a connector for the nichrome wire and a 270kohm pull-down resistor. To control the burn, the current flow through the MOSFET is controlled via a GPIO pin on the FM430. As a safeguard, if the GPIO input goes to a float for any reason, the pull-down resistor defaults the MOSFET to not allow current to flow through the nichrome wire.

The feedback circuits confirm the deployment of the gravity boom and antenna. This is done by reading the bit values of the GPIO pins connected to the output of each feedback circuit. If the bit read high, then the pins of the header are no longer shorted together indicating successful deployment. Otherwise, deployment has not occurred successfully.
Figure 6. The gravity boom nichrome burn circuits are on the left and the deployment feedback circuits are on the right.

**THERMAL**

Majority of the work spent designing the share board went into the temperature monitoring circuit. This circuit measures the temperature of all six sides of the satellite as well as the temperature of the battery and transmitter. The team plans to store these temperatures and send them down as part of the telemetry data during the next window of opportunity.

The temperature monitoring circuit can be divided into two distinct parts: the temperature measurement and digitizing that measurement. The temperature measurements are performed by NTC thermistors manufactured by Quality Thermistor. Surface temperature measurements will be taken of the solar cell boards, transceiver and battery.

<table>
<thead>
<tr>
<th>Surface Mount</th>
<th>Surface temperature probe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part Number</td>
<td>QT0603Z-104G</td>
</tr>
<tr>
<td>Resistance Tolerance</td>
<td>+/- 2%</td>
</tr>
<tr>
<td>Resistance at 25degC</td>
<td>100kOhm</td>
</tr>
<tr>
<td>Curve Type</td>
<td>Z</td>
</tr>
</tbody>
</table>

*The Steinhart-Hart Equation*

Both thermistors have a negative temperature coefficient meaning that the thermistor’s resistance decreases as the temperature increases. The temperature vs. resistance follows the Steinhart-Hart equation:

\[
\frac{1}{T} = A + B \ln R + C \ln(R)^2
\]  

(Eq. 2)

where A,B, and C are curve fitting coefficients given by the thermistor manufacturer for the temperature range you are planning to measure T and R are the resistance and temperature of the thermistor respectively [5].
**Temperature Span**

Data acquired by CalPoly SLO's CP3 temperature sensors indicate that at an orbit with an apogee of 787.5km and perigee of 659.5km the temperature fluctuations were at most +/- 30degC. To the best of our knowledge, temperature measurements have not been performed for a circular orbit at 400km at an inclination of 60deg. So, to allow a slightly wider temperature fluctuation, a temperature measurement range of -45degC to 60degC was chosen arbitrarily for Kumua'o.

Table 4. The Steinhart-Hart coefficients for the two types of thermistors given by Quality Thermistor.

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>QT0603Z-104G</th>
<th>QT06005-190</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6.2011E-4</td>
<td>1.1293E-3</td>
</tr>
<tr>
<td>B</td>
<td>2.2791E-4</td>
<td>2.3406E-4</td>
</tr>
<tr>
<td>C</td>
<td>7.2000E-8</td>
<td>8.8096E-8</td>
</tr>
</tbody>
</table>

**Thermistor Resistance Limits**

By choosing the temperature measurement range of -45deg to 60degC, the maximum and minimum resistances for each type of thermistor can be obtained from Quality Thermistor. These resistances take into account the tolerances therefore they are the worst case resistances.

Table 5. The resistance values for the thermistors at the ends of the temperature measurement range.

<table>
<thead>
<tr>
<th>Thermistor</th>
<th>Temperature</th>
<th>Resistance (kohm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>QT0603Z-104G</td>
<td>-45degC</td>
<td>4460.830</td>
</tr>
<tr>
<td></td>
<td>60degC</td>
<td>24.08384</td>
</tr>
<tr>
<td>QT06005-190</td>
<td>-45degC</td>
<td>431.9590</td>
</tr>
<tr>
<td></td>
<td>60degC</td>
<td>2.333740</td>
</tr>
</tbody>
</table>

The values in table 5 were used to determine the worst case voltage divider output swings.

**The voltage divider**

Each thermistor is placed at the top side of a voltage divider with a fixed resistance bottom resistor. The input to each voltage divider is a fixed voltage provided by the REF5025 by Texas Instruments, a 2.5V voltage reference. The voltage divider can be described by the following equation:

\[
V_{out} = \left( \frac{R_1}{R_1 + R_o} \right) V_{in} \tag{Eq. 3}
\]

where \(V_{out}\) is the output of the voltage, \(V_{in}\) is the input voltage, \(R_1\) is the resistance of the bottom resistor, and \(R_2\) is the resistance of the top resistor. In our case, \(R_2\) is the resistance of the thermistor.
**Bottom Resistor Value**

The value of the bottom side resistor for each voltage divider can be chosen arbitrarily as long as all voltage dividers do not collectively sink more current than the voltage reference can provide. However, to maximize the voltage swing at the output of the voltage divider, the bottom resistor value must be chosen carefully. To do this, the voltage swing was calculated for various bottom resistors values at both the maximum and minimum temperature resistances using Eq. 3. Then, the voltage difference was normalized with respect to the input voltage by dividing the difference by 2.5V. The normalized values represent the percentage of the input voltage that the output will swing if the thermistor were to sweep the entire measurement range from -45degC to 60degC. In short, the closer the normalized value is to 1, the higher the voltage swing and the higher the percentage used of the usable output voltage span.

The maximum normalized swing value for the voltage divider containing the QT0603Z-104G surface mount thermistor is 0.87 occurring at a bottom resistor value of 345kohms. Whereas for the QT06005-190 surface temperature probe divider, the maximum normalized swing value is also about 0.87 occurring at a bottom resistor value of 35kohms. By choosing the bottom resistor values close to these values, the least amount of ADC resolution will be wasted without using voltage amplifier gains of greater than 1.0.

![Figure 7. Here is a buffered voltage divider with the top resistor as the surface mount thermistor](image)

![Figure 8. Swing percentage vs. bottom resistor value for voltage divider using QT0603Z-104G surface mount thermistor as top resistor](image)

![Figure 9. Swing percentage vs. bottom resistor value for voltage divider using QT06005-190 surface temperature probe as top resistor](image)
**Interfacing with the ADC**

To maintain accuracy in using the voltage divider equation, all eight voltage dividers are buffered using a voltage follower. This ensures that little current will be sourced by the voltage divider to perform the measurement since the op amp has high input impedance. To reduce the amount of components on the share board and to maintain simplicity, all the voltage followers have unity gain.

The use of two TLV2474 quad op amp ICs were chosen to interface all eight voltage dividers to the ADC. As part of the TLV247x family manufactured by Texas instruments, the TLV2474 contains four rail to rail input/output operational amplifiers that use only a single supply.

The chosen ADC for the temperature monitoring circuit is the 8-channel AD7998 by Analog Devices.

**Digitizer Resolution**

The resolution of the ADC has a large effect on the precision of the temperature measurements acquired by the temperature monitoring circuit. The higher the resolution the more precise of measurement acquired. The ADC chosen for the temperature monitoring board is the AD7998 by Analog Devices. It has eight single-ended analog input channels measuring each of the voltage divider outputs with 12-bit precision. The same reference voltage provided by the REF5025 for all the thermistor voltage dividers is the same reference provided for the AD7998. Knowing this, the voltage step, $Q$, of the AD7998 is

$$Q = \frac{V_{\text{ref}}}{N} = \frac{2.5V}{2^{12}} = 0.611 \text{ mV/bit}$$  \hspace{1cm} \text{(Eq. 4)}$$

where $V_{\text{ref}}$ is the reference voltage of the REF5025 and $N$ is the resolution of the ADC. We are providing the AD7998 a reference voltage of 2.5V and it has a 12-bit resolution containing a total of 4095 quantization steps. The calculation using Eq. 4 represents the conversion precision to +/- 0.5 the least significant bit.

Since the voltage followers have unity gain, the output voltage spans of the dividers will not utilize the full dynamic range of the ADC. Assuming that the bottom resistances are chosen to maximize the use of the ADC’s dynamic range, only about 2.125V of the 2.5V will be used by each voltage divider if temperatures from -45degC to 60degC were measured. This leaves about
325mV of the range that is useless. This translates to a dynamic range loss of about 13%.

**Temperature calculation**

Now that the chosen ADC has been discussed, it is known how the voltages from the dividers will be measured. Knowing this, Eq. 2 can be expanded to use the value of the ADC directly to calculate the resistance of the thermistors and ultimately the temperature measurement. By solving Eq. 3 for the thermistor resistance and substituting into the Eq. 2, the temperature can be computing according to the following:

\[
T = \frac{A + B \ln \left( R_2 \left( \frac{V_{in}}{V_{out}} - 1 \right) \right) + C \ln \left( R_1 \left( \frac{V_{in}}{V_{out}} - 1 \right) \right)}{D}
\]  

(Eq. 5)

where \( V_{in} \) can be the 12-bit value of the ADC reading and \( V_{out} = 4096 \) representing the ADC value at the reference voltage. By using the ADC 12-bit values directly, the actual voltages do not need to be calculated saving the processor time in calculations.

**The PCA9517A**

For the FM430, both I2C & SPI clock signals are merged into a single pin on the PC104 bus. In addition the SPI data out and I2C data signals occupy the same pin. So both SPI and I2C buses cannot be used as the same time. To manage this, all I2C devices will be connected to the I2C/SPI data out bus via a PCA9517A I2C bus repeater manufactured by NXP Semiconductors. This repeater is designed to perform level shifting between low voltage and high voltage I2C buses as well as extend the I2C bus by buffering the SDA and SCL lines. However, these features are not the reasons this part was chosen. Instead, the repeater has open-drain inputs and outputs such that when the repeater is disabled, the inputs and outputs go to a high impedance state allowing the I2C lines float. This will allow SPI devices to communicate using the same pins on the PC104 bus without interfering with one another. By disabling the I2C repeater, control over these shared lines are given to SPI devices.

![Figure 11](image.jpg)

Figure 11. Here the PCA9517A has pull up resistors on its inputs and outputs.
**The MAX890**

To conserve power while the temperature monitoring circuit is not in use, the op amps, ADC and voltage reference can be turned off by the MAX890 P-channel switch. This switch is controlled by FM430 GPIO signal named THERMA_CTL. When this signal is low, power will be delivered to the op amps, ADC, and voltage divider. Otherwise, if the signal is high or floating, the switch will default via pull up resistor to not allow any current to pass though.

![Figure 12. Here is the MAX890 IC in the share board circuit.](image)

**FUTURE WORK**

Currently, the share board’s circuit schematic is considered completed in first draft form. The only foreseen change to make to the share board schematic is swapping out structure’s IRL540 MOSFETs for ones with smaller packages. However, only testing will tell for sure whether or not the circuit needs to be changed. The most critical item that is suspect to change is the Morse tone circuit that is composed of the low pass filter and a tone switcher. This is because the output of the filter has tight tolerances as the output requirements are in the mV range. The filter might require some tuning after the board is built.

The PCB layout for the board started in March however due to constant revisions and additions to the share board it was decided to complete the schematic to a stable form first. As a result the PCB layout is only about 30% completed. Having said this, the immediate next step is to complete the PCB layout and submit the design to Advanced Circuits for manufacture.

After the board is assembled, the next step would be to test the board. Table 6 outlines several tests that seem logical to perform.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural</td>
<td>Power</td>
<td>Supply 6V, 3.3V, and GND to the board and probe power pins on all devices to confirm that they are getting power or if they are shorted.</td>
</tr>
<tr>
<td>Structural</td>
<td>Burn</td>
<td>Connect 9V battery connector and attempt to manually burn monofilament line.</td>
</tr>
<tr>
<td>Structural</td>
<td>Deployment</td>
<td>Read voltage values from feedbacks to confirm that they are working properly</td>
</tr>
</tbody>
</table>
Telecomm | Filter | Generate PWM train at 1020Hz and probe the output of the filter to confirm that a sine wave at near 5Vpp is generated.
---|---|---
Telecomm | Morse Tone | Pull TEL_PTT to logic high, send PWM square wave through TEL_MICROPHONEROPHONE, pull TEL_MUXCTL low and toggle TONE_CTL to hear if tone is transmitted over radio.
Telecomm | Packet Radio | Pull TEL_MUXCTL high and send data to see if received on other end.
Thermal | Room Temp Test | Pull THEMA_CTL low, probe the output of all eight op amps to measure the voltage output of each divider. Calculate temperature to see if all the temperature at room temperature.
Thermal | I2C Temp reading | Pull THEMA_CTL low and get data display values to verify similar in temperature.
Thermal | Elevated temp I2C reading | Place board on warm object, Pull THEMA_CTL low, poll ADC and display values to verify elevated temperature.
General | I2C Disconnect | Pull enable to low and probe I2C SCL and SDA are

For the I2C temperature tests, the sampling code needs to be written to acquire the digitized values. This will be done soon after the circuit is built. A driver will be written to command the burns for antenna deployment, transmit Morse tones, and acquire temperature using functions written for each subsystem. If the team desires to restore 12-bit resolution to the effective dynamic range for the voltage dividers oversampling and decimation might be used.

**CONCLUSION**

This paper describes the development process of the share board. Containing circuits for three subsystems, its main design intention is to save space within the PC104 stack of Kumua`o. The Thermal and Telecommunication subsystem portions are described in detail from the theory that describes the requirements for the circuitry and then the circuits meeting those requirements are described. The performance of the low pass filter for the telecomm circuit is simulated in PSpice to aid in selecting the proper component values. Each main part of the thermal circuit is described in detail including the voltage divider, ADC interfacing, and the ADC. A description of interpreting the ADC output and calculating the temperature measurement is outlined. Finally, a brief description is given of the tests that will be performed on the share board after assembly.

Being a mechanical engineering major, designing this board has been particularly challenging. Since I am considering pursuing an Electrical Engineering MS, this is great experience for me and I hope to continue doing this kind of work to get my feet wet.

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REFERENCES


Appendix
1. PC104 Bus
2. Structural Schematic
3. Telecomm Schematic
4. Thermal Schematic