From Radio Oceanography Laboratory wiki

Tech: Testing VSWR Pro Mods

Modifications to the VSWR Protection Board

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To the modified Bi-Directional Coupler ==>>

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The Other Half: The Raspberry Pi Controller
The Third Half ;>) The TOMCO Transmitter

The testing 9/11-9/13 has gone well. Everything works pretty much as expected. The board does exert proper control over the TOMCO.

- There were a few minor problems encountered
- There were some new insights that resulted from the testing and **especially** from my discussions with Ian.
- Ian is firing up the Raspberry Pi to begin testing the basic over-ride and control functions

THE BOARD IS FULLY ROUTED AND GERBER FILES GENERATED.

ALL CHANGES LISTED BELOW HAVE BEEN UPDATED ON THE PCB.

IT PASSES THE FULL DFM CHECK WITH NO ERRORS.

A TYPICAL/SEMI-TYPICAL EXTENDED BOARD DESIGN.

The design of the RF section of this board (typically the most challenging) was not too difficult in this case.
Here there were some complex interactions which were not fully anticipated in the initial design. **See "SPICE Thinking" page**
There were some off-board interactions with both the Raspberry Pi Analog/Digital board and the TOMCO RF Amplifier that had to be accommodated:

1. The input impedance of the Analog port turned out to be surprisingly low.
2. The input impedance of the TOMCO gain-reduction port is not even specified and had to be measured.
3. Actions by this board and reactions by the TOMCO must be coordinated.
4. It did not occur to me that the relay contact "break-before-make" would upset the discriminator.

20-20 hindsight is a wonderful talent ;>) but sometimes there are practical limits to what can be anticipated.
For reasons like these, it is often unrealistic to attempt to make a perfect board on the first try with no prototype.
In this case, I fully expected that a prototype board would realistically be required.
On the other hand, "prototype software" sometimes drags out for years and nobody seems to notice.

CHANGES

The Bi-directional Coupler will provide samples of the Forward and Reflected power levels.
A AD8307 RSSI (*Relative Signal Strength Indicator*) chip has an analog output that is very linear **in dBm**.
There is an equation to covert that voltage to real dBm. (The slope is 26mV/dB, with a 2.12 volt offset.)

- The Raspberry Pi can monitor that in **calibrated** power levels that are meaningful. (1.715 volts = ????)
- Discriminators can detect exact trip levels for protecting the TOMCO RF amplifier.

(The trimpot on the Bi-directional Coupler is for setting the null at perfect load match, it does not calibrate amplitude.)

We decided that the best way to calibrate the system is with the Raspberry Pi.
This is "backwards": Instead of providing calibration coefficients to each Raspberry Pi, the RSSI system is calibrated to give correct readings in software.
So the display should be formatted something like this:

```
Drive Power in:       -6.90dBm
Forward Power:        46.2dBm
Reflected Power:      25.8dBm
TOMCO current:         3.75A
TOMCO Temperature:    52.5C
Heatsink Temperature: 48.9C
TRACO voltage:        26.8V
System Supply:        28.5V
```

We are adding a trimpot (variable attenuator) at the input of each RSSI.
With the trimpot adjusted, a 47.0 dBm signal will produce a RSSI voltage which produces a screen reeading of 47.0dBm.
Thus the variability of the coupler, the RSSI chip, ADC channel,etc. are all calibrated out with a single trimpot to produce a voltage that the software thinks is 47.0 dBm.
This is reasonable, because all elements are reasonably accurate.
Each trigger point voltage is then essentially **identical** on all protection boards.
If the setpoints are pre-set to the **nominal** values with a DVM, the board should be fully functional at first power-up.
I added test points for pre-setting these levels.

Changes proposed and implemented: Add the three 50-ohm trimpots for channel calibration.
Convert multiple components to surface mount to optimize production.
Fix the hysteresis issue with the input power monitor.
There was a similar hysteresis problem with the temperature sensor.
The -10dB reduced power control input impedance is not specified. When we tested the input, it is around 3k.

- While the CMOS gate is low enough impedance to drive this, a simple voltage divider to modify the gain reduction would raise the output impedance, so I added a simple emitter follower.

The input impedance of the A/D converter initially selected on the Raspberry Pi A/D was too low: 16.8K. This would load the RSSI signals unacceptably, so two LMV324 quad rail-to-rail op amp buffers were added.
The new ADC board has higher impedance (marginally acceptable) but the buffers remain a good precaution and they are cheap.

The schematic was too congested to make the changes and maintain clarity, so I had to move it to a larger sheet.
When the new netlist is checked against the old Protel file, **all changes should be properly identified.**
Indeed a DRC with the OLD netlist and NEW netlist remained the same.
The circuit has changed considerably now, so that test can't be repeated, but it was important to get it right once before making chnages.
I also needed room for ample circuit notations for clarity.

TOP

Board Fixes

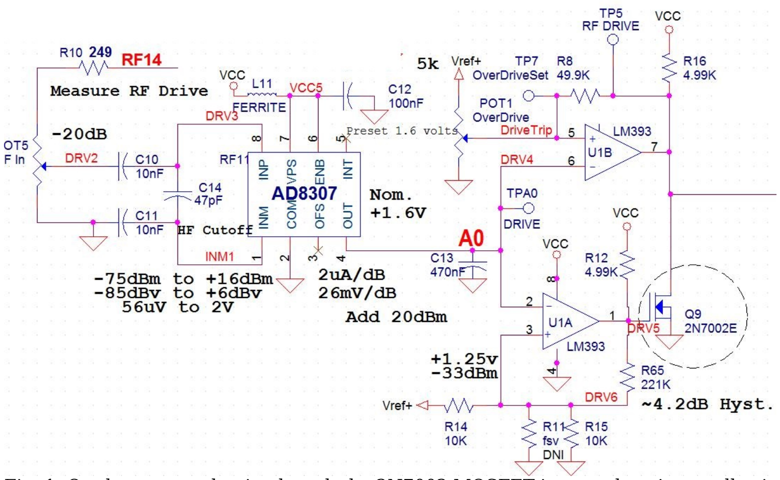

Fig. 1. On the new production board, the 2N7002 MOSFET inverts the trigger, allowing the RSSI output to be connected to the non-inverting input, which is very high impedance.
The hysteresis was causing about a 2.5dB jump in the measured voltage at threshold. This was confusing, both real time and in the logged data.

The relay contacts are break-before-make, so during transition there is a brief spike in the (unloaded) RF voltage. When **reducing** the level, that spike retriggered the discriminator, causing a relay chatter. C13 was increased to slow down the response and the hysteresis was increased by changing R65.

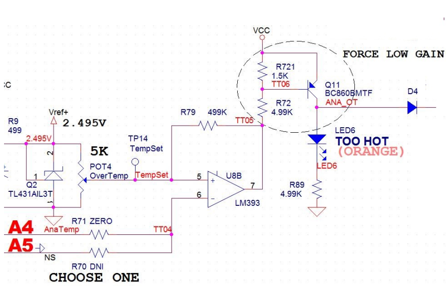

Fig. 2. The temperature channel trip had the same hysteresis problem.

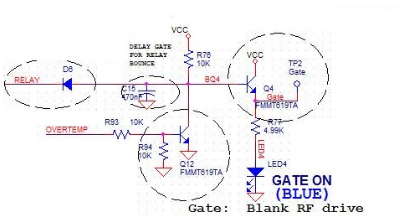

Fig. 3. The Gate LED was changed to logical "Gate ON": in idle state ALL LEDs are OFF.

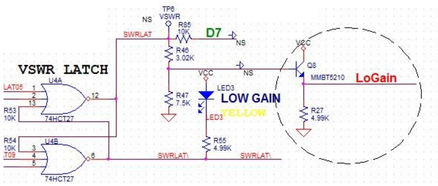

Fig. 4. The -10dB RF Gain on the TOMCO has an input impedance in the low K-ohm range, so it needs an emitter follower.

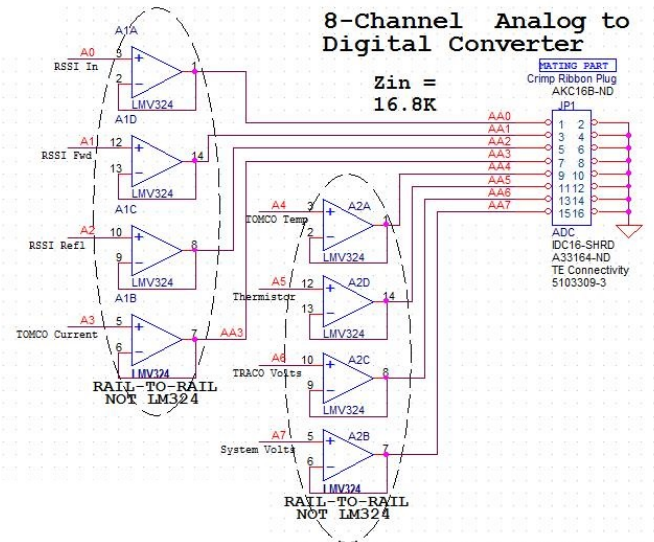

Fig. 5. The Raspberry Pi Analog Board 16.8K inputs would load the RSSI signals, so two LMV324 quad **rail-to-rail** buffers were added. (Note that the LM324 is NOT suitable.)

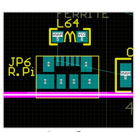

Fig. 6. The Raspberry Pi uses a Micro-USB cable just for power. So I added one to the VSWR Board so that we can just use a standard cable for power.

Other Considerations:

MCI makes a pin-compatible parallel programmed digital attenuator. You don't have to power things down for five seconds to change the DIP switches. If we don't anticipate getting the SPI running for some time, we might consider getting the Mexico boards populated with these, to make the DIPswitch unconfusing. **On the other hand, it now appears that programming the "pseudo-SPI" will be fairly simple.**

TOP

DIO Lines

Raspberry Note: The I/O board is 5 volt logic: Change the pull-downs to 100K. There are no level shifting issues.
There were numerous changes required after prototype testing, requiring circuit changes, some additional parts, etc.
The DIO connector has changed.
The digital section was un-routed so that the parts could be re-arranged for optimum routing.
A new netlist was generated and checked.
The new parts have been placed, and that section was auto-routed routed.

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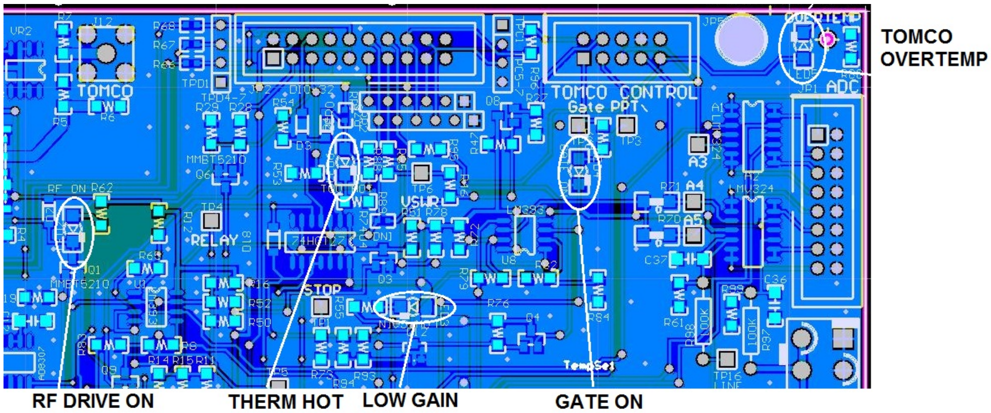
LED Status Indicators



		VSWR Protection Status						
		LED2 GREEN RF RELAY	LED3 YELLOW LOW GAIN	LED4 BLUE GATE ON	LED5 RED HOT	LED6 ORANGE HeatSink	ARM Indications	Comment
1	IDLE	OFF	OFF	OFF				
2	RF DRIVE ON	ON		ON			A0 OK	
3	RF Overdrive						A0 High	Not Latched
4	VSWR fault	ON	=>ON	ON			A2 High	Low Power -7 to -10 dB
5	FWD Power Fault	ON	=>ON	ON			A1 High	Low Power -7 to -10 dB
6	TOMCO TEMP Flag	ON	=>ON		ON		A4 TOMCO Internal Temp	Power stage bias off
7	Heatsink Thermistor	ON	=>ON	ON		ON	A5 Heatsink Temperature	
8	RF Drive Off	OFF	Reset	OFF				
			Latched				A3 TOMCO Internal Current	

Table 1. LED Status Display

1. During the idle state, **ALL LEDs ARE OFF** and the Low-gain latch is reset.
2. When RF drive is initiated, only the green RF Relay and blue Gate ON are lighted.
3. If the RF drive is turned too high, the LEDs go OFF (Idle State) to protect the TOMCO. This is not latched, and the lights come back on when the drive is reduced. (This is presumably during setup.)
4. If there is a VSWR fault, the yellow Low Gain warning LED comes on. TOMCO gain is reduced by 7-10dB. The RF Drive must be recycled to reset the latch.
5. If there is a Forward Power Fault (Pout >55 Watts) the yellow Low Gain LED comes on (latched). That will presumably bring the power into a safe range.
6. The TOMCO internal Hot Flag is a **HARD ERROR** that you can't override. The bias is removed from the output stage to force a cool-down.
7. If the heatsink gets too hot, the power will be reduced by 7-10dB. That will presumably allow the system to still gather data. If the temperature continues to rise, the TOMCO internal Hot Flag will terminate the cycle.
8. End of data cycle, remove RF drive. The Low Gain latch is reset for the next cycle. All lights out (idle).

DISCUSSION

4a. If there is a VSWR fault, it will generally happen immediately upon transmission. The power will be reduced from 50 Watts to 10 Watts to protect the TOMCO. Predictably, the range will be reduced, but we will still get data. This is the preferred scenario.

4b. A nearby lightning strike or other transient event could trigger a VSWR fault. (AM transmitters at Kakaako caused faults.) For short transients, I increased the filter capacitors on the RSSI chips to reduce the effects of sub-millisecond transients. These could be increased further.

4c. For transient trips in mid data file, it remains to be seen how useable a file is when taken with a step down in power. We won't know until we try...

6a. The TOMCO internal temperature alarm is an emergency. It cannot be overriden by the ARM. It immediately removes bias from the power output stage which dramatically reduces the heat load.

6b. When the ARM is in the loop, it will terminate the data cycle and log the error.

6c. In autonomous mode, when the TOMCO cools off, the continued RF input drive will resume operation. This MAY result in the TOMCO overheating again and recycling. It therefore seems prudent to switch to 10 Watts to mitigate the probable repeat problem.

6d. The TOMCO must remain powered up so that we can continue to monitor the temperature to know when it is ok to fully power back up.

TOP

Production Version

This is the NEW VSWR Protection board. IT IS FULLY ROUTED. IT PASSED DFM CHECK WITH ZERO ERRORS.

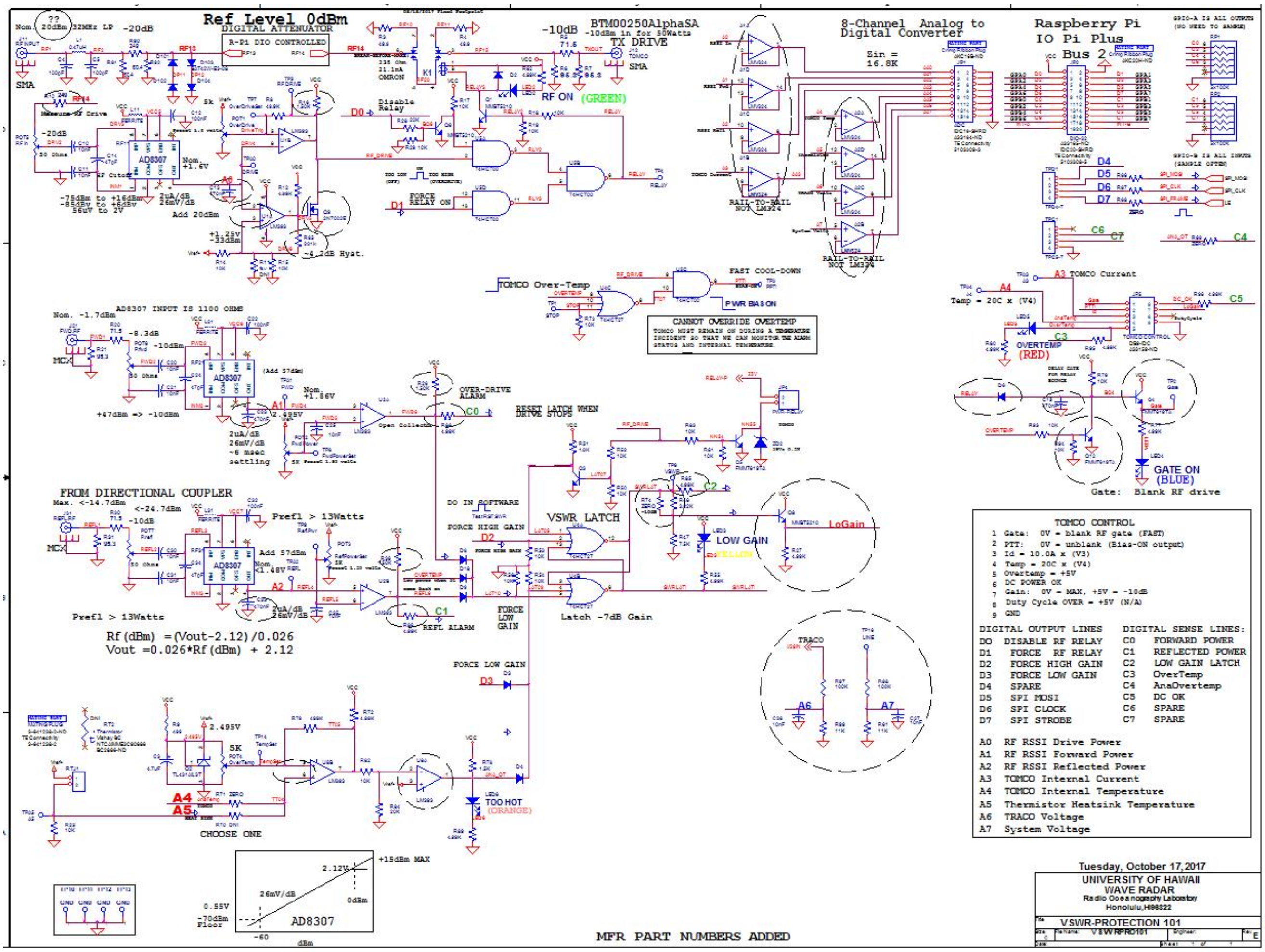


Fig. 8. The Complete schematic. Circuit changes are circled.

Fig. 9. Completed PCB layout. Annular Ring errors corrected.
No room for a Micro-USB facing down mechanically. Moved to the side. ==>>>
Mounting holes are locked (same position as before). Board expanded 0.5" to the right.

The gain pots at the RSSI inputs are placed, and other pots were replaced with surface mount, but the RSSI section is otherwise unchanged.
There were numerous changes required after prototype testing, requiring circuit changes, some additional parts, etc.
The digital section was un-routed so that the parts could be re-arranged.
A new netlist was generated and checked.
The new parts have been placed, and fully routed.
The DIO connector has changed to match the Raspberrry Pi boards.

TOP

DFM Check

I ran a FreeDFM at Advanced Circuits to ensure that there are no Gerber file errors.
This is an automated free service which runs a full computer check of design rules.
It does not include of course the manual checks by PCB technicians in the ON-HOLD department, checking individual probable violations.

The FreeDFM found no serious errors:

What FreeDFM found on your design

Show Stoppers

We Found None!

Problems Automatically Fixed

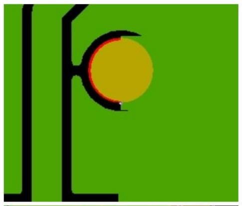
Insufficient Soldermask Clearance (9 violations) 1 2 3 4 5

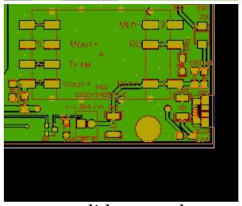
But it did find some technical violations which might be a problem:

Insufficient Soldermask Clearance (9 violations)

Requirements: We require a minimum of .003" soldermask clearance. This is achieved by a soldermask relief .006" larger than the associated copper pad.

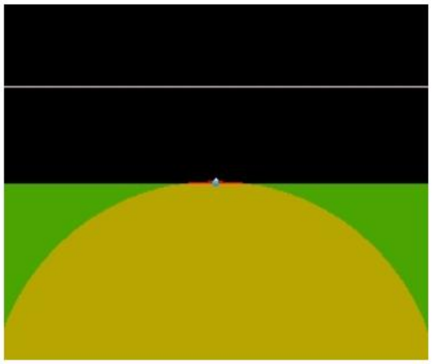
Resolution: While too small a relief can cause your pads to be partially covered by soldermask, too large a clearance can cause traces to be exposed, causing problems during assembly. The best method is to set all your soldermask reliefs .006 in. larger than their associated pad.

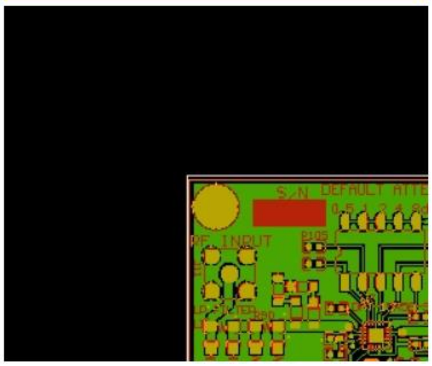




The computer did not understand the context. It simply interprets strict rules.
The DC-DC converter module has ground pins on the metal shield.
These are not assigned pin numbers in the library model so the netlist does not ground them.
I "illegally" placed fills on the board to ground there pins. That eliminates the "clearance" -- on purpose.
A.C. would automatically "restore" that clearance, so I have to OK this "non-error".
Aode does not even check for clearance violations.

Undersized soldermask clearance of 1.95 mils on layer vswpr8dh.GTS, at X=2.713", Y=3.425975".





The four mounting holes are indeed grounded in the netlist, but on the PCB there are just four thin Thermal Relief traces on each.
For a solid ground, I place a fill patch. This is intentional, not an error.
This accounts for four "potential errors".

Note that it is also common to place a keepout around a mounting screw to avoid any auto-routed traces being placed here.
Routing out all of the mounting holes would of course be a disaster.
TOP