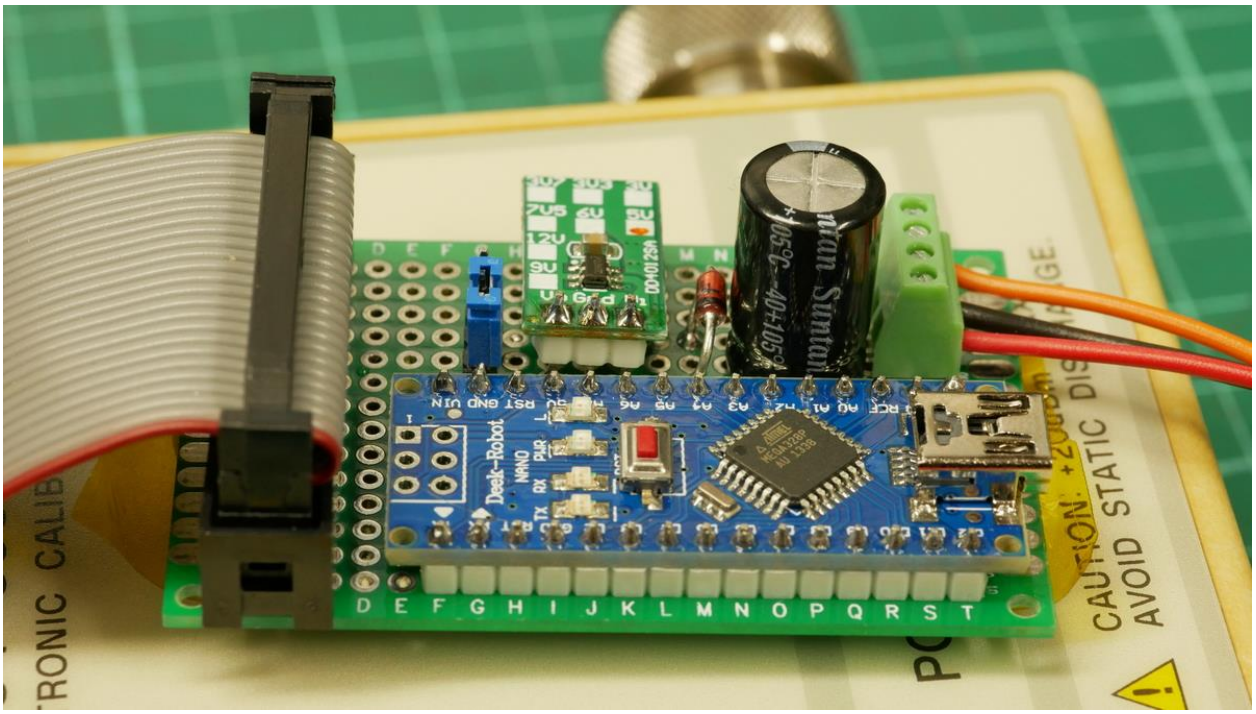
Arduino Based Diagnostic Board for HP 8506x Series ECal Pods



Introduction

Building on the reverse engineering of the HP 85062 ECal Pods performed by Steffan[1] there was a need to control the module to extract and compare the calibration data, as well as control the module for diagnostic troubleshooting purposes

Given the interface consisted of a 8 bit bus multiplexed into 5 registers plus a few control and strobe lines running at 5V TTL logic levels the venerable Arduino development boards were the ideal choice for manual control and dumping of formation.

The diagnostic board is capable of the following operations:

1. Dump the EEPROM contents for reverse engineering purposes
2. Manually set the 16 gate signals which drive the PIN switches along the ECal path

Currently not supported, but technically feasible using this design, is the ability to reprogram the EEPOM with updated calibration data. A supplemental utility has also been written to convert the HEX listing and extract the calibration data in Touchstone format.

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Hardware

This project has been developed and tested on using an Arduino Nano but can be adapted to others in the Arduino family depending on what's on hand. Note that the sketch breaks form the Arduino libraries and directly manipulates the ATMega328 ports (specifically PORTB and PORTD) making it an exercise for the reader to adapt to other Arduino boards.

Construction consists of mounting the Arduino on a development perforated board and soldering connections using kapton wire-wrap wire, or similar, to connect up the Arduino pins to the DB25 connector. Conveniently I had a DB25 terminated on an IDC header plug, but you may choose to wire directly to the DB25.

A 100uF 50V capacitor was added to the 24V supply rail along with a 27V Zener to provide a basic level of protection.

Connection between the D25 and Arduino along with the power connections is as follows:

```
 * Arduino Pin  DB25 Pin  Port  Dir   Description
 * ------------------------------------------------------------------
 *     D0                            Reserved TX Out
 *     D1                            Reserved RX In
 *     D2        13        PD2   I/O   ECal Data bus bit 0
 *     D3        25        PD3   I/O   ECal Data bus bit 1
 *     D4        12        PD4   I/O   ECal Data bus bit 2
 *     D5        24        PD5   I/O   ECal Data bus bit 3
 *     D6        11        PD6   I/O   ECal Data bus bit 4
 *     D7        23        PD7   I/O   ECal Data bus bit 5
 *     D8        10        PB0   I/O   ECal Data bus bit 6
 *     D9        22        PB1   I/O   ECal Data bus bit 7
 *     D10        9        PB2   Out   Mux A0
 *     D11       21        PB3   Out   Mux A1
 *     D12        8        PB4   Out   Mux A2
 *     D13       20        PB5   Out   ClkP [Data latched on rising edge]
 *     A0         7        PA0   Out   OE to EEPROM
 *     A1        19        PA1   Out   WR to EEPROM
 *     A2         6        PA2   Out   MR Master Reset all latches
 *
 *     GND        2                    Digital Ground
 *     GND       15                    Digital Ground
 *     +5V        3                    VCC Digital (< 50mA - OK to power from Arduino)
 *     -12V      17                    Analog -12v
 *     +5V       16                    Analog 5v
 *     +24V       1                    Analog +24V (20-24V @ 750mA Startup)
 *     GND       14                    Analog Ground
```

For reference the Arduino Nano pinout below can be used:

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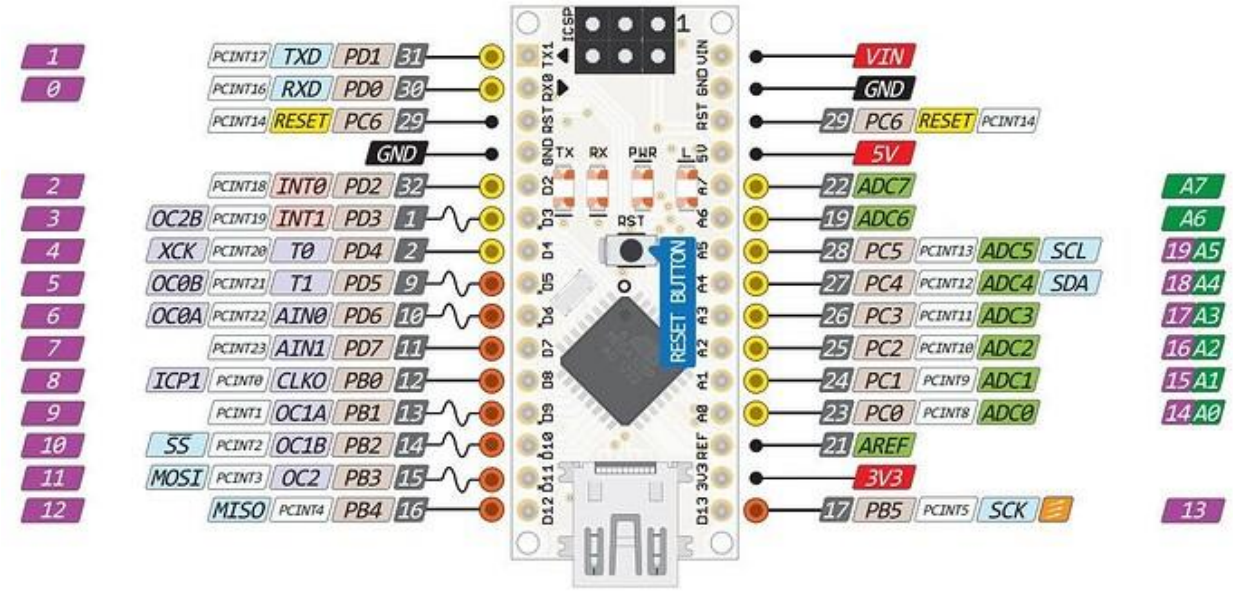

Power

The digital +5V supply on pin 3 of the DB25 connector powers the logic chips inside of the ECal module with a total current draw of less than 50mA. This can be supplied by the +5V pin from the Arduino which allows the module EEPROM to be read and confirm basic operation.

The low band modules (to 2GHz) only require the -12V supply to activate the PIN Switches. Similarly for the high band module the Analog +5V supply is required to activate the PIN switches along with +24V to heat the module to its calibration temperature. The +24V Rail is not critical with no variation in calibration performance down to 16V

The Analog +5V rail was derived from the +24V supply using a 7805 compatible SMPS converter module. If using a lower supply voltage a 7805 can be considered, or simply removed if you have a suitable triple rail supply. Note that 42mA per activated switch is required and during normal use only 3 switches are activated together but with manual control it's possible to set all switches(set all command) requiring 525mA current.

Required Voltages and current draw:

Supply	EEPROM Access	Low Band Module	High Band Module
+5V Digital @ 50mA	☑	☑	☑
+5V Analog ~42mA per switch ~525mA max	-	-	☑
-12V ~20mA	-	☑	-
+24V ~750mA Startup	-	(No heater)	☑

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~120mA after 15mins

Arduino Software

I assume the reader is familiar with Arduino concepts. If not google "Getting Started with Arduino" for some starting guidance on setting up the Arduino IDE and connecting to a development board.

Once the sketch is compiled and downloaded (There are 2 files for this project) you need to fire up the terminal on the designated serial port at 115200 Baud 8-N-1

Upon successful startup the following greeting will appear to confirm successful connection:

```
HP 85062/85064 eCal manual control

Model Number             : 85064-60001
Serial Number            : 00896
Connector Type           : N5FN5M RF1
Last Certification       : 9 Sep 1998
Module number of points : 80
Recommended warmup time : 0s
>
```

If the module interface isn't working you will see the following startup message

```
HP 85062/85064 eCal manual control

Module not responding
>
```

Troubleshooting:

- If garbage is seen instead of the above check the baud rate is 115200
- If the Model Number / Serial number is grabbled check the D0 to D7 lines are correct and not broken/shorted.
- If you get "cannot open port" error then open device manager and navigate to Ports (COM & LPT) and confirm the correct port detected.
- If "Module Not Responding" error is seen at startup check the module is connected, and that all the Arduino signals are connected as per these instructions

The Help command gives an overview of the commands

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```
> help

dump [start] [end]    Dump EEPROM data
info          Display ECal revision details
set n         Enable switch n
set n,m,...   Multiple values seperated by comma
set n1-n2     Range with dash
set 0xHHHH    Set using hex value
set all       Enable all switches
set none      Disable all switches
walk          Walk switch bits 1 through 16
```

For example the set command can be used to activate a PIN Switch/Gate and can be used in several forms to set a single bit up to a series of bits.

```
> set 1-5

        :                   1 1 1 1 1 1 1 :
  Gate  : 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 :
Status  : X X X X X - - - - - - - - - - - : 0x001F
> set none

        :                   1 1 1 1 1 1 1 :
  Gate  : 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 :
Status  : - - - - - - - - - - - - - - - - : 0x0000
> set 0xff

        :                   1 1 1 1 1 1 1 :
  Gate  : 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 :
Status  : X X X X X X X X - - - - - - - - : 0x00FF
> set none

        :                   1 1 1 1 1 1 1 :
  Gate  : 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 :
Status  : - - - - - - - - - - - - - - - - : 0x0000
```

The EEPROM contents can be dumped using the “dump” command. If no range is specified the entire 256K contents are dumped

```
> dump 0x0 0x100

000000: 48 50 38 35 30 36 30 43 20 45 43 41 4C 00 85 C0  | HP85060C ECAL... |
000010: 7C 25 E8 7F 64 00 4E 6F 76 20 32 38 20 31 39 39  | |%..d.Nov 28 199 |
000020: 34 00 FF FF FF FF FF FF FF FF FF FF FF FF FF FF  | 4............... |
000030: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  | ................ |
000040: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  | ................ |
000050: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  | ................ |
000060: FF FF FF FF 30 30 38 39 36 00 06 58 0A 00 00 EB  | ....00896..X.... |
000070: 4E 35 46 4E 35 4D 20 52 46 31 00 C6 06 5B 0A 00  | N5FN5M RF1...[.. |
000080: F6 06 8C 06 39 20 53 65 70 20 31 39 39 38 20 00  | ....9 Sep 1998 . |
000090: 48 2D 50 2F 4D 54 41 00 06 08 74 07 83 3E 8A 06  | H-P/MTA...t..>.. |
0000A0: 00 75 35 31 C0 50 E8 19 0B 83 C4 02 FF 36 90 06  | .u51.P.......6.. |
0000B0: 31 C0 50 E8 88 0A 83 C4 30 31 2E 30 30 00 00 10  | 1.P.....01.00... |
```


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```
0000C0: C7 06 96 06 00 00 B8 A8 06 50 E8 4A 00 00 00 00  | .........P.J.... |
0000D0: 2A 75 85 41 00 00 00 00 65 CD DD 41 50 00 00 00  | *u.A....e..AP... |
0000E0: 00 00 00 00 84 D7 97 41 67 00 5B 00 00 00 01 00  | .......Ag.[..... |
0000F0: 38 35 30 36 34 2D 36 30 30 30 31 00 01 00 50 E8  | 85064-60001...P. |
```

For digital troubleshooting the "walk" command performs a cylon wipe pattern across all 16 PIN control signals until a key is pressed to terminate the test. This is useful for confirming the inter board signals are correct, as well as confirming each switch is toggling. Check pin1 through 16 of the inter board connector are being activated in sequence

Note that for the low band module only the first 7 control signals are routed to the lower board, and U5 contains jumper wires for U5 only. The actual mapping and voltages have yet to be documented.

```
> walk

Walking bits 1 through 16.  Press any key to terminate
................................................................................
................................................................................
................................................................................
................................................................................
.........................................*Terminated*
```

For the high band module the 16 control lines toggle between +24V (off) and +5V (on)

For the low band module the 7 control lines are TTL which switch FT1 and FT8 in opposition with -12V.

Data Extraction Script

The included Python script ECal_dump.py can be used to extract the data from a captured dump command into a series of touchstone files for further analysis. This requires Python 3 to be installed in the path.

The format of the output file is the ECal_<*model*>_<*serial*>_<set>_<hex_switch>.sXp

Where Model and Serial number are the values extracted from the dump file, and the hex_switch value represents the PIN switch configuration to match the data.

The Low band module contains 4 calibration datasets for each port plus a 2 port verification standard (#008F) and finally a through calibration(#0073).

```
Y:\WDK\HP 85062 ECal>python ECal_dump.py HP85062-60005.txt
Model Number            : 85062-60005
Serial Number           : 00359
Connector Type          : 35F35F RF1
Last Certification      : 9 Aug 2001
```


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```
Start Frequency         : 45 MHz
End Frequency           : 2000 MHz
Step                    : 100 MHz
Number of points        : 80
Recommended warmup time : 0 seconds


**********************************************
**  Switch Data:  0x007D 0x007E 0x004F 0x00DB
**********************************************
Writing file ECal_HP_85062-60005_SN00359_set1_sw#007D.s1p
Writing file ECal HP 85062-60005 SN00359 set1 sw#007E.s1p
Writing file ECal_HP_85062-60005_SN00359_set1_sw#004F.s1p
Writing file ECal_HP_85062-60005_SN00359_set1_sw#00DB.s1p

**********************************************
**  Switch Data:  0x007D 0x007E 0x004F 0x0027
**********************************************
Writing file ECal_HP_85062-60005_SN00359_set2_sw#007D.s1p
Writing file ECal_HP_85062-60005_SN00359_set2_sw#007E.s1p
Writing file ECal_HP_85062-60005_SN00359_set2_sw#004F.s1p
Writing file ECal_HP_85062-60005_SN00359_set2_sw#0027.s1p

**********************************************
**  Switch Data:  0x0073
**********************************************
Writing file ECal_HP_85062-60005_SN00359_set3_sw#0073.s2p

**********************************************
**  Switch Data:  0x008F
**********************************************
Writing file ECal_HP_85062-60005_SN00359_set4_sw#008F.s2p

Y:\WDK\HP 85062 ECal>
```

The High band module consists of 13 calibration points for each port followed by a 2 port through reference and verification standard (#0200)

```
Y:\WDK\HP 85062 ECal>python ECal_dump.py HP85062-60006.txt
Model Number            : 85062-60006
Serial Number           : 00367
Connector Type          : 35F35F MW1
Last Certification      : 8 Aug 2001
Start Frequency         : 1000 MHz
End Frequency           : 26500 MHz
Step                    : 100 MHz
Number of points        : 256
Recommended warmup time : 300 seconds


**********************************************
**  Switch Data:  0x8003 0x4003 0x2003 0x1003 0x0803 0x0403 0x0103 0x0083 0x0043
 0x0023 0x0013 0x000B 0x0007
**********************************************
Writing file ECal_HP_85062-60006_SN00367_set1_sw#8003.s1p
Writing file ECal_HP_85062-60006_SN00367_set1_sw#4003.s1p
```


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```
Writing file ECal_HP_85062-60006_SN00367_set1_sw#2003.s1p
Writing file ECal_HP_85062-60006_SN00367_set1_sw#1003.s1p
Writing file ECal_HP_85062-60006_SN00367_set1_sw#0803.s1p
Writing file ECal_HP_85062-60006_SN00367_set1_sw#0403.s1p
Writing file ECal_HP_85062-60006_SN00367_set1_sw#0103.s1p
Writing file ECal_HP_85062-60006_SN00367_set1_sw#0083.s1p
Writing file ECal_HP_85062-60006_SN00367_set1_sw#0043.s1p
Writing file ECal_HP_85062-60006_SN00367_set1_sw#0023.s1p
Writing file ECal_HP_85062-60006_SN00367_set1_sw#0013.s1p
Writing file ECal_HP_85062-60006_SN00367_set1_sw#000B.s1p
Writing file ECal_HP_85062-60006_SN00367_set1_sw#0007.s1p

*********************************************
**  Switch Data:  0xC001 0xC002 0xC004 0xC008 0xC010 0xC020 0xC080 0xC100 0xC200
 0xC400 0xC800 0xD000 0xE000
*********************************************
Writing file ECal_HP_85062-60006_SN00367_set2_sw#C001.s1p
Writing file ECal_HP_85062-60006_SN00367_set2_sw#C002.s1p
Writing file ECal_HP_85062-60006_SN00367_set2_sw#C004.s1p
Writing file ECal_HP_85062-60006_SN00367_set2_sw#C008.s1p
Writing file ECal_HP_85062-60006_SN00367_set2_sw#C010.s1p
Writing file ECal_HP_85062-60006_SN00367_set2_sw#C020.s1p
Writing file ECal_HP_85062-60006_SN00367_set2_sw#C080.s1p
Writing file ECal_HP_85062-60006_SN00367_set2_sw#C100.s1p
Writing file ECal_HP_85062-60006_SN00367_set2_sw#C200.s1p
Writing file ECal_HP_85062-60006_SN00367_set2_sw#C400.s1p
Writing file ECal_HP_85062-60006_SN00367_set2_sw#C800.s1p
Writing file ECal_HP_85062-60006_SN00367_set2_sw#D000.s1p
Writing file ECal_HP_85062-60006_SN00367_set2_sw#E000.s1p

*********************************************
**  Switch Data:  0x0000
*********************************************
Writing file ECal_HP_85062-60006_SN00367_set3_sw#0000.s2p

*********************************************
**  Switch Data:  0x0200
*********************************************
Writing file ECal_HP_85062-60006_SN00367_set4_sw#0200.s2p

Y:\WDK\HP 85062 ECal>
```

Comparing the through verification data extracted from the EEPROM against a manual SLOT calibration confirms the extracted data matches the actual performance of the ECal module.

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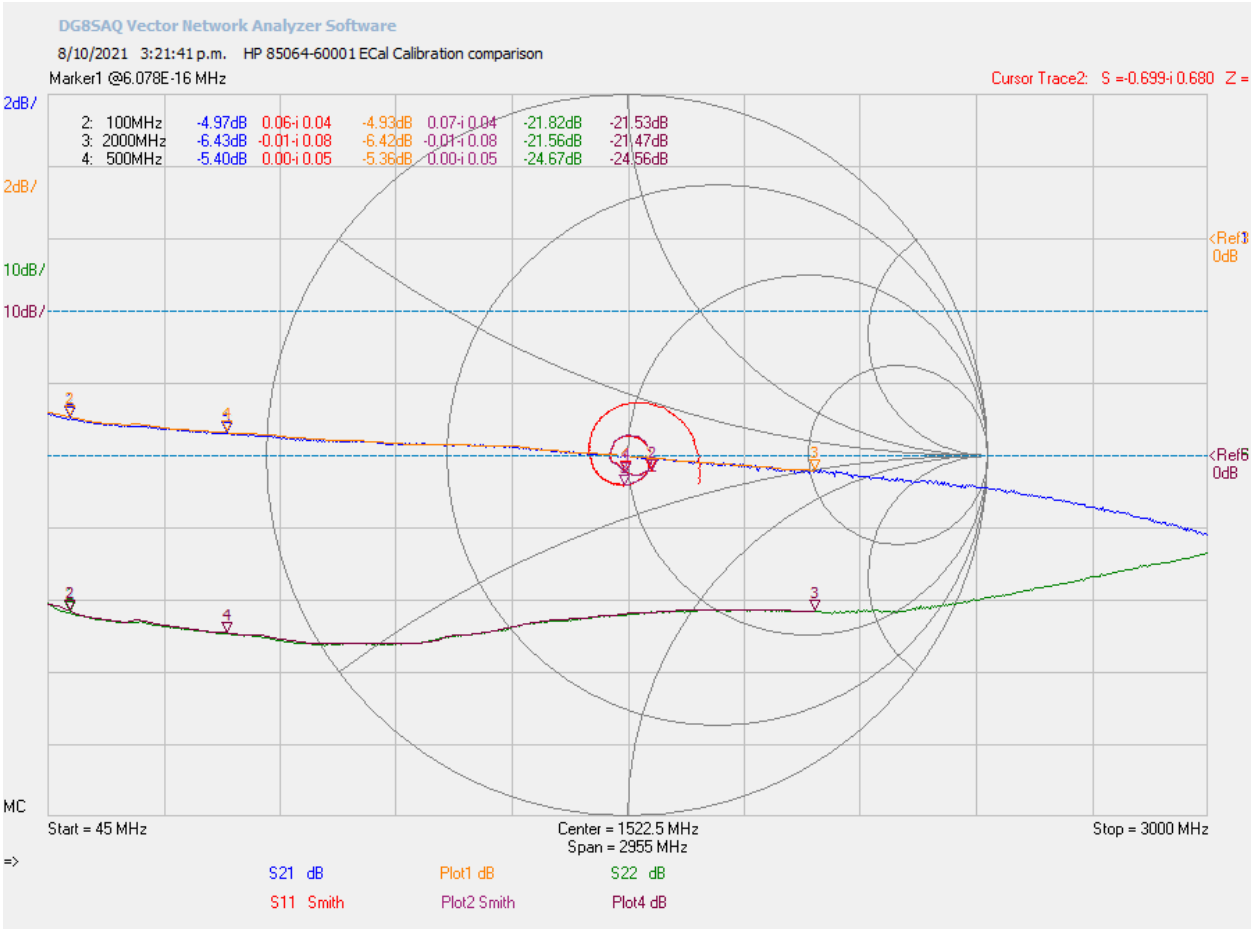

85064-60001 Internal Photos

The Low Band module uses the same control PCB with RP1, RP2, U5, U6 and U7 not populated. The first 7 control signals are bridged (see wire jumpers near the label for RP1)

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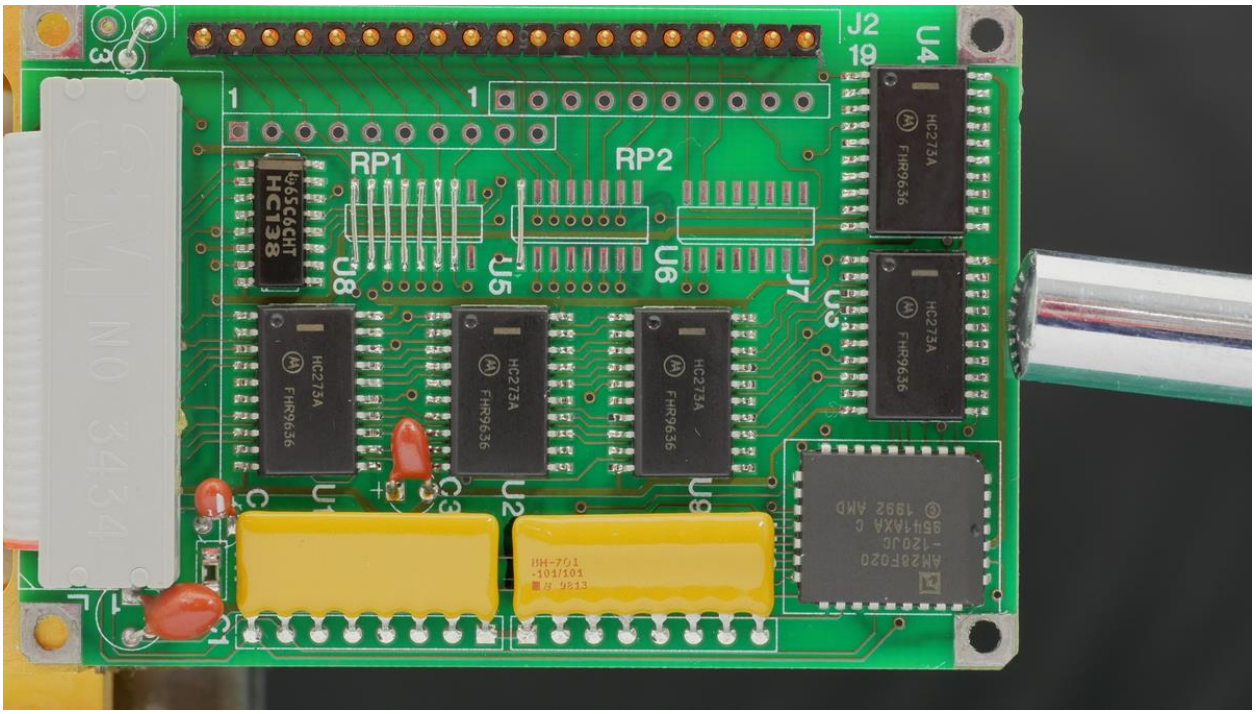

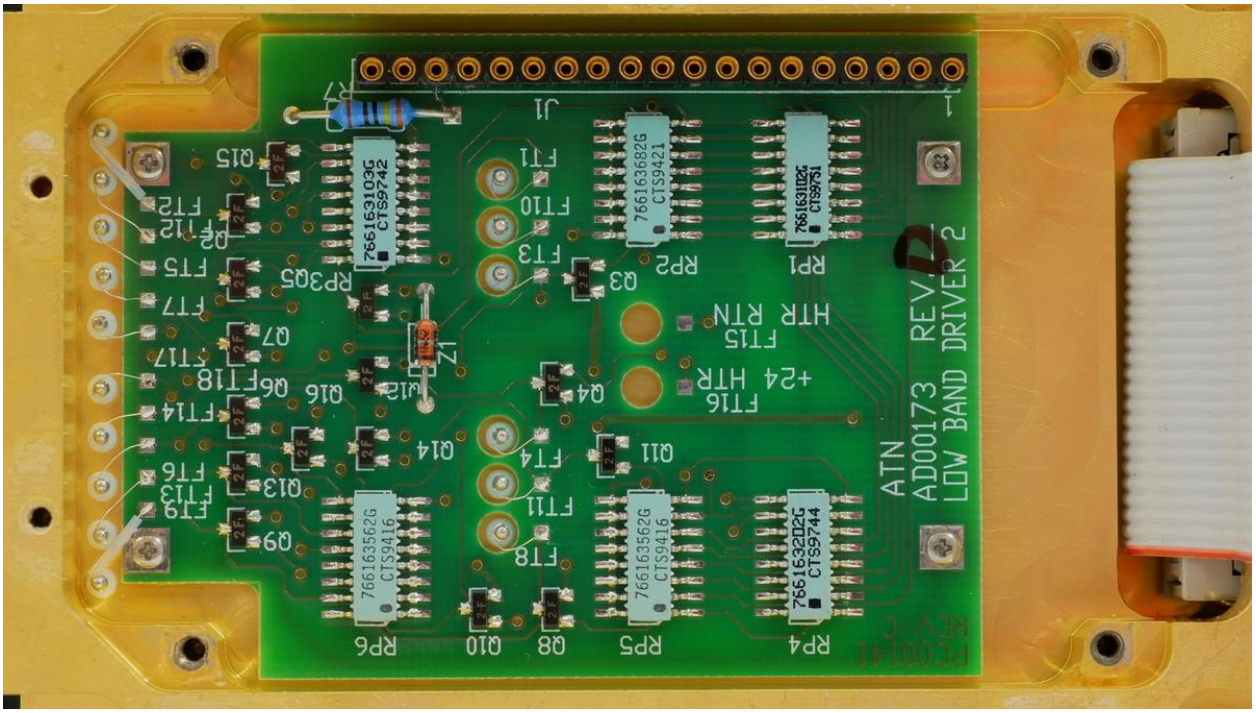

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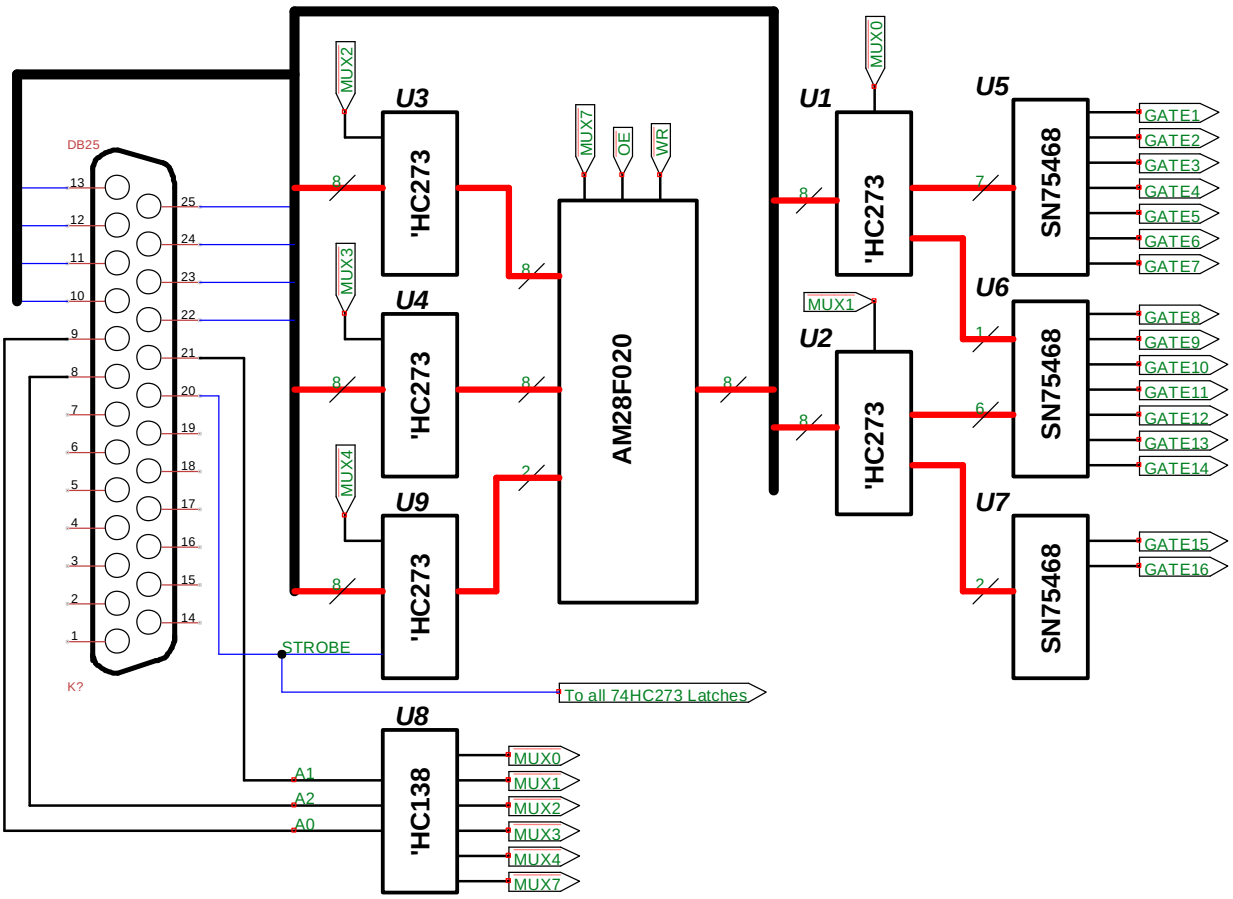
ECal Interface Block Diagram[2]

For troubleshooting the interface board the following block diagram outlines how the signals flow through the module. Refer to the datasheets for the specific device and connections are self-explanatory, ie. D0 connects to D0 of the 74HC273 latches and lower output bits connect to lower inputs of following stage.



[1] HP-Agilent-Keysight groups file ECAL 85062-6006.pdf

[2] Drawn in TinyCad

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