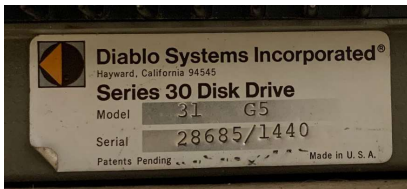


## Diablo Model 31, G5, serial number 28685/1440, Restoration Notes



### Restoration list:

1. ✓ Check all polarized capacitors and replace bad ones
2. ✓ Confirm how the drive is configured, which options
3. ✓ Verify jumper options on backplane: Select Line Jumper and Attention Option Jumper, refer to section 2.2.3.5 in the manual
4. ✓ Replace the air filter
5. ✓ Current consumption with nothing running, just idle (smoke test)
6. ✓ Clean the disk cartridge and spin up disk
7. ✓ Verify index and sector pulses, verify sector address signals
8. ✓ Read data from disk cartridge and check it using the emulator
9. ✓ Write a bootable OS-8 image onto the disk cartridge and boot up OS-8 on the PDP-8/m

### Confirm the Module Versions:

- J1 – PCB 11077 Rev J, SCH 11078 Rev 00M
- J2 – PCB 11110 Rev J, SCH 11111 Rev H, 11111-00 option
- J3 – PCB 11024 Rev N, SCH 11026 Rev L, 11026-02 (Attention Line Negative, has A10 & A15, no A13)
- J8 – PCB 11083 Rev J, SCH 11085 Rev P (no jumper E19; relay F43 is installed)
- J9 – PCB 11069 Rev K, SCH 11071 Rev ?
- J10 – PCB 11080 Rev J, SCH 11082-10 Rev AA,  
Resistors H28 11.5K $\Omega$ , H56 ?, Jumpers F9 10 $\Omega$ , F39 n/c, K28 10 $\Omega$ ,  
Terminator Resistors F41 n/c, D39 n/c, D44 n/c, E42 n/c, H41 n/c,  
Input Clamp Diodes E39 n/c, F8 n/c, Timing Resistors F28 1 Meg $\Omega$ , H53 75K $\Omega$

			DESCRIPTION																		
			1440 BPS OPTION 005	1562K BPS OPTION 004	DAISY CHAIN OPTION 006	ERASE GATE OPTION 007	INTERRUPT OPTION 048	RESISTORS		JUMPERS		TERMINATOR RESISTORS						INPUT CLAMP DIODES		TIMING RESISTORS	
ASSY.NO.	REV	ECO NO.						H28	H56	F9	F39	K28	F41	D39	D44	E42	H41	E39	F8	F28	H53
11082-08	AA	8187	X					11.5K	11.5K	10Ω		10Ω	150Ω	150Ω	150Ω	150Ω	150Ω			F28 SELECTED TO GIVE DATA	
11082-09	AA	8187	X			X		11.5K	11.5K	10Ω		10Ω	150Ω	150Ω	150Ω	150Ω	150Ω	IN4454	IN4454	GATE TIMING OF 515 ± 10ns.	
11082-10	AA	8187	X		X			11.5K	11.5K	10Ω		10Ω	150Ω	150Ω	150Ω	150Ω	150Ω	IN4454	IN4454	H53 SELECTED TO GIVE DATA	
11082-11	AA	8187	X		X	X		11.5K	11.5K	10Ω		10Ω	150Ω	150Ω	150Ω	150Ω	150Ω	IN4454	IN4454	GATE TIMING OF 485 ± 10ns.	
11082-12	AA	8187		X				10.5K	10.5K	10Ω		10Ω	150Ω	150Ω	150Ω	150Ω	150Ω	IN4454	IN4454	F28 SELECTED TO GIVE DATA	
11082-13	AA	8187		X		X		10.5K	10.5K	10Ω		10Ω	150Ω	150Ω	150Ω	150Ω	150Ω	IN4454	IN4454	GATE TIMING OF 470 ± 15ns.	
11082-14	AA	8187		X	X			10.5K	10.5K	10Ω		10Ω	150Ω	150Ω	150Ω	150Ω	150Ω	IN4454	IN4454	H53 SELECTED TO GIVE DATA	
11082-15	AA	8187		X	X	X		10.5K	10.5K	10Ω		10Ω	150Ω	150Ω	150Ω	150Ω	150Ω	IN4454	IN4454	GATE TIMING OF 450 ± 10ns.	
11082-16	AA	8187		X	X	X	X	10.5K	10.5K	10Ω		10Ω	150Ω	150Ω	150Ω	150Ω	150Ω	IN4454	IN4454		

Mistake,  
should be 003

Mistake,  
should be 003

### Checking all polarized capacitors:

J	Loc.	Desc	good	bad
J1	A4	100 $\mu$ F 20V, Ta, DxL = 8.8x19.5mm, C = 97 $\mu$ F, ESR = 1.7 $\Omega$ , reformed @18V	✓	
J1	D7	100 $\mu$ F 25V, Al, DxL = 9.6x20mm, C = 119 $\mu$ F, ESR = 1.8 $\Omega$ , reformed @20V	✓	
J1	K3	100 $\mu$ F 25V, Al, DxL = 9.6x20mm, C = 120 $\mu$ F, ESR = 1.9 $\Omega$ , reformed @20V	✓	
J2	A7	100 $\mu$ F 25V, Al, DxL = 9.6x20mm, C = 140 $\mu$ F, ESR = 1.6 $\Omega$ , reformed @20V	✓	
J2	B27	2.2 $\mu$ F 35V, Ta, DxL = 4.6x12mm, C = 2.6 $\mu$ F, ESR = 2.4 $\Omega$ , reformed @30V	✓	
J3	B7	100 $\mu$ F 25V, Al, DxL = 9.6x20mm, C = 138 $\mu$ F, ESR = 1.7 $\Omega$ , reformed @20V	✓	
J3	F35	10 $\mu$ F 25V, Al, DxL = 9.6x20mm, short at 7 $\Omega$		✓
J8	A3	10 $\mu$ F 25V, Al, DxL = 6.7x15mm, C = 5.4 $\mu$ F, ESR = 36 $\Omega$ , reformed @20V		✓
J8	A6	10 $\mu$ F 25V, Al, DxL = 6.7x15mm, C = 13 $\mu$ F, ESR = 3.9 $\Omega$ , reformed @20V	✓	
J8	D6	22 $\mu$ F 35V, Ta, DxL = 7.3x17mm, C = 25 $\mu$ F, ESR = 1.5 $\Omega$ , reformed @30V	✓	
J8	H3	22 $\mu$ F 35V, Ta, DxL = 7.3x17mm, C = 26 $\mu$ F, ESR = 1.5 $\Omega$ , reformed @30V	✓	
J9	A4	10 $\mu$ F 25V, Al, DxL = 6.7x15mm, C = 13.7 $\mu$ F, ESR = 3.2 $\Omega$ , reformed @20V Initially, this appeared to be shorted in the reforming test.	✓	
J9	A10	10 $\mu$ F 25V, Al, DxL = 6.7x15mm, C = 14.9 $\mu$ F, ESR = 4.4 $\Omega$ , reformed @20V	✓	
J9	E4	10 $\mu$ F 25V, Al, DxL = 6.7x15mm, C = 14.4 $\mu$ F, ESR = 4.2 $\Omega$ , reformed @20V	✓	
J9	H1	10 $\mu$ F 25V, Al, DxL = 6.7x15mm, C = 16.8 $\mu$ F, ESR = 4.2 $\Omega$ , reformed @20V	✓	
J9	K30	10 $\mu$ F 25V, Al, DxL = 6.7x15mm, C = 13.6 $\mu$ F, ESR = 4.2 $\Omega$ , reformed @20V	✓	
J9	K36	12 $\mu$ F 20V, Ta, DxL = 4.7x12mm, C = 12.7 $\mu$ F, ESR = 4.1 $\Omega$ , reformed @18V	✓	
J9	K48	39 $\mu$ F 10V, Ta, DxL = 4.7x12mm, C = 43.7 $\mu$ F, ESR = 1.3 $\Omega$ , reformed @9V	✓	
J10	B3	10 $\mu$ F 25V, Al, DxL = 6.7x15mm, C = 11.0 $\mu$ F, ESR = 48 $\Omega$ , reformed @20V		✓
J10	B7	10 $\mu$ F 25V, Al, DxL = 6.7x15mm, C = 48 pF, ESR = $\Omega$ , reformed @20V		✓
J10	E9	10 $\mu$ F 25V, Al, DxL = 6.7x15mm, C = 9.0 $\mu$ F, ESR = 108 $\Omega$ , reformed @20V		✓
J10	K3	10 $\mu$ F 25V, Al, DxL = 6.7x15mm, C = 11.3 $\mu$ F, ESR = 117 $\Omega$ , reformed @20V		✓
J10	H30	10 $\mu$ F 25V, Al, DxL = 6.7x15mm, C = 49 pF, ESR = $\Omega$ , reformed @20V		✓
J10	A71	12 $\mu$ F 20V, Ta, DxL = 4.7x12mm, C = 14.5 $\mu$ F, ESR = 2.2 $\Omega$ , reformed @18V	✓	
J10	A74	12 $\mu$ F 20V, Ta, DxL = 4.7x12mm, C = 13.5 $\mu$ F, ESR = 2.0 $\Omega$ , reformed @18V	✓	

### All Capacitors (total of 25):

- Qty 4 – 100  $\mu$ F 25V, Al, DxL = 9.6x20mm
- Qty 13 – 10  $\mu$ F 25V, Al, DxL = 9.6x20mm
- Qty 1 – 100  $\mu$ F 20V, Ta, DxL = 8.8x19.5mm
- Qty 1 – 2.2  $\mu$ F 35V, Ta, DxL = 4.6x12mm
- Qty 2 – 22  $\mu$ F 35V, Ta, DxL = 7.3x17mm
- Qty 3 – 12  $\mu$ F 20V, Ta, DxL = 4.7x12mm
- Qty 1 – 39  $\mu$ F 10V, Ta, DxL = 4.7x12mm

### Bad Capacitors (total of 7):

- Qty 7 – 10  $\mu$ F 25V, Al, DxL = 9.6x20mm

### Jumper & Component Configuration Option Settings:

Select: “2” (which is drive 1 per DEC definitions)

Attention: “2” (jumper to pin M, which is “\* High Density Indication”)

Other choices are:

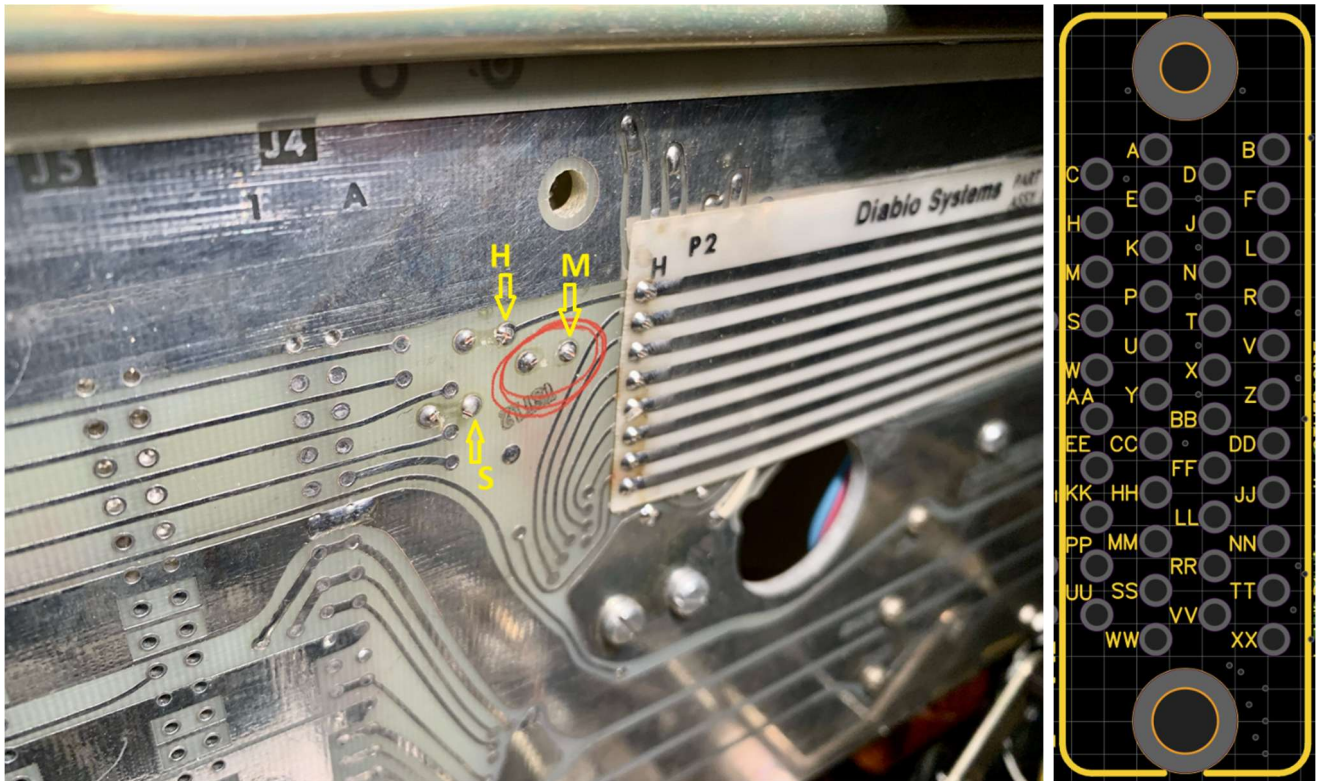
- “1” (jumper to pin H, Write Protect Input)
- “3” (jumper to pin S, \*Pseudo Sector Mark)
- “4” (jumper to pin XX, \*Logical Address Interlock)

Opt.	Description	Notes
060	Paint – Gray/Green without logo	Paint on cover
046	Attention Line Negative	J3 – jumpers A10 & A15 installed, jumper A13 open, 11026-02 Attention Line Negative
003	1440 kHz – 2040BPI – Option	J10 – component & jumper placement options
005	Write Protect – not included	J9 – components removed for Write Protect
006	Daisy Chain Option	J10 – component & jumper placement, terminator resistors removed
007	Erase Gate – not included	J10 – component & jumper placement, F9 installed
046	Attention Line Negative	J3 – jumpers A10 & A15 installed, jumper A13 open, 11026-02 Attention Line Negative
048	Interrupt Option – not included	J10 – component & jumper placement, F39 not installed

**Table 6-1 Series 30 Options**

Y	N	Option	Description
	✓	001	720 kHz – 1020BPI – IBM Compatible
	✓	002	781 kHz – 1100BPI – Diablo Standard
✓		003	1440 kHz – 2040BPI – Option
	✓	004	1562 kHz – 2200BPI – Option
	✓	005	Write Protect
	✓	008	Erase Gate (Not tied to Write Gate)
	✓	013	Paint – Orange with Diablo Logo
	✓	014	Paint – Orange without Logo
	✓	015	Unpainted without logo
	✓	017	Flangless Mount (table top trim)
	✓	018	Flush Mount
	✓	019	Extended Front
	✓	020	Upper and Lower Trim for Flush Mount
	✓	023	Drive Tester with Read/Write Data
		024	Extender Board Assembly
		025	Standard Density – 8 Sector
		026	High Density – 8 Sector
		027	Standard Density Alignment Pack
		029	Dual Unit Power Supply
		030	High Density Alignment Pack
		032	Power Supply Cable
		033-05'	Receptacle Connectors on 5' flat cable (female)
		033-07'	Receptacle Connectors on 7' flat cable (female)
		034-05'	Pin Connectors on 5' flat cable (male)
		034-07'	Pin Connectors on 7' flat cable (male)
		035	Receptacle terminator resistors (female)
		036	Pin terminator resistors (male)
		037	Receptacle terminator without resistors (female)
		038	Pin terminator without resistors (mail)
		039	Standard Density – 12 Sector
		040	Standard Density – 24 Sector
		041	High Density – 12 Sector
		042	High Density – 24 Sector
		043	Option 023 using external power
		044	Rack Mounting for Power Supply
	✓	045	Paint – Orange without Logo
		046	Attention Line Negative
		047	Attention Line Positive
	✓	048	Interrupt Option
		050	DTC Card FPC Interdata Controller
		051	Standard Density – 16 Sector
		052	High Density – 16 Sector
		053-05'	M/F Cable 5'
		053-07'	M/F Cable 7'
		054	32 Sector
		056	Cable Assembly (Interdata Controller)
		057	Terminator (no erase gate) Female with resistors
		058	Terminator (no erase gate) Male with resistors
✓		060	Paint – Gray/Green without logo
	✓	061	Paint – Blue without logo
	✓	062	Grained without logo
	✓	063	Paint – White White (Varian)
		064	Attention line with logical address interlock (Varian)
		065	Cartridge Closing Bail Assembly

There's a problem with the "High Density Indication" signal on pin M, it's inactive when the drive is spun up and drive is selected. Traced it back to the module in J10 where I can see that "High Density Indication" is active. The schematics show a jumper on the backplane. Found it!



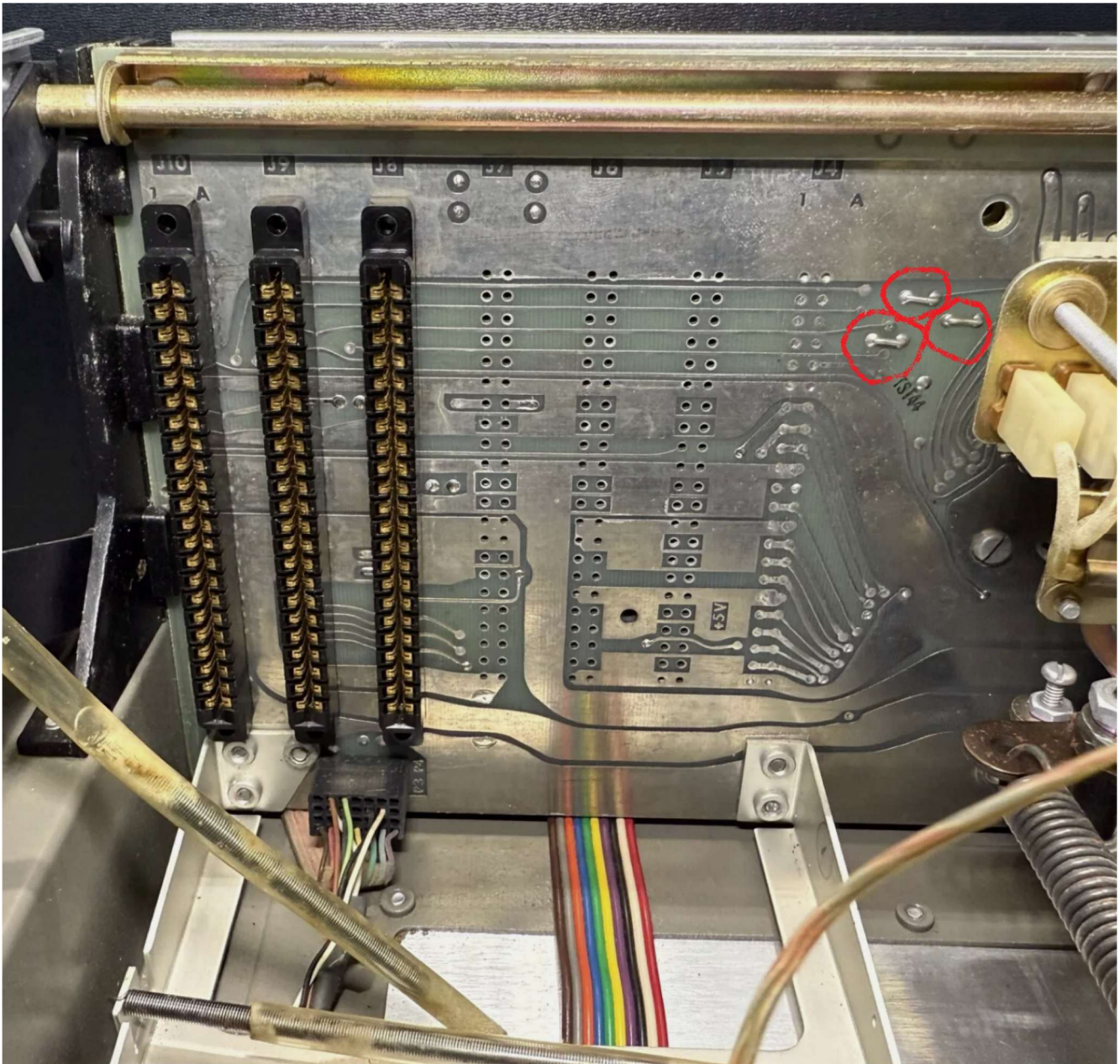
The jumpers for the signals on MRAC pins H, M, and S were apparently removed by the previous owner.

- H – “Write Protect Input”
- M – “High Density Indication”
- S – “Pseudo Sector Mark”

It's strange that the board in J10 is configured for high density but the backplane jumper for the “High Density Indication” signal is removed



For example, this is another drive, photo captured from an eBay listing, that has all three jumpers installed:



**March 12, 2025**

Added the “High Density Indication” jumper on the backplane.

Spun up the drive, “Display Status” shows the following response:

```
tester-0>disp status
  Drive Address =      0
  Addr Encoded (RK11D mode) = 0
  controller =      RK8-E
  bitRate =      1440000
  preamble1Length = 120
  preamble2Length = 82
    total bit_times_sector_to_start = 202
  bit_times_data_bits_after_start = 3104
  postambleLength = 36
  numberOfCylinders =      203
  numberOfSectorsPerTrack = 16
  numberOfHeads =      2
  microsecondsPerSector = 2500
  tester board version = 2
  emulator board version = 2

  Drive Status 1 = 0x18

  Drive Status 2 = 0x7
tester-0>
```

There were no exceptions flagged regarding Drive Status 1 & 2, so we can proceed.

Entered the disk read command and the following is the response:

```
tester-0>disk read first.rke
  External Disk Read Image.
  external drive is ready
  microSD card is present
  filesystem started
  microSD LED is on
  opening the disk image file
  file_open_write_disk_image_n 'FIRST.RKE'
sd_spi_go_low_frequency: Actual frequency: 398089
V2-Version Card
R3/R7: 0x1aa
R3/R7: 0xff8000
R3/R7: 0x80ff8000
Card Initialized: Standard Capacity Card: Version 2.x
SD card initialized
Standard Capacity: c_size: 239
Sectors: 0x3c000 : 245760
Capacity: 0x7800000 : 120 MB
sd_spi_go_high_frequency: Actual frequency: 12500000
filename = FIRST.RKE
  writing the file header
  Writing header to file 'FIRST.RKE'
  Reading external disk data
    cylinder = 0
### ERROR, read command time exceeded in disk_read_image reading data,
  Check the controller mode setting, DISP STATUS, then MODE CONT <setting>
tester-0>
```

It seems possible that bad index or sector pulses or sector address signals might cause this.

Confirmed that index and sector pulses and sector address signals are valid, so that's not the problem.

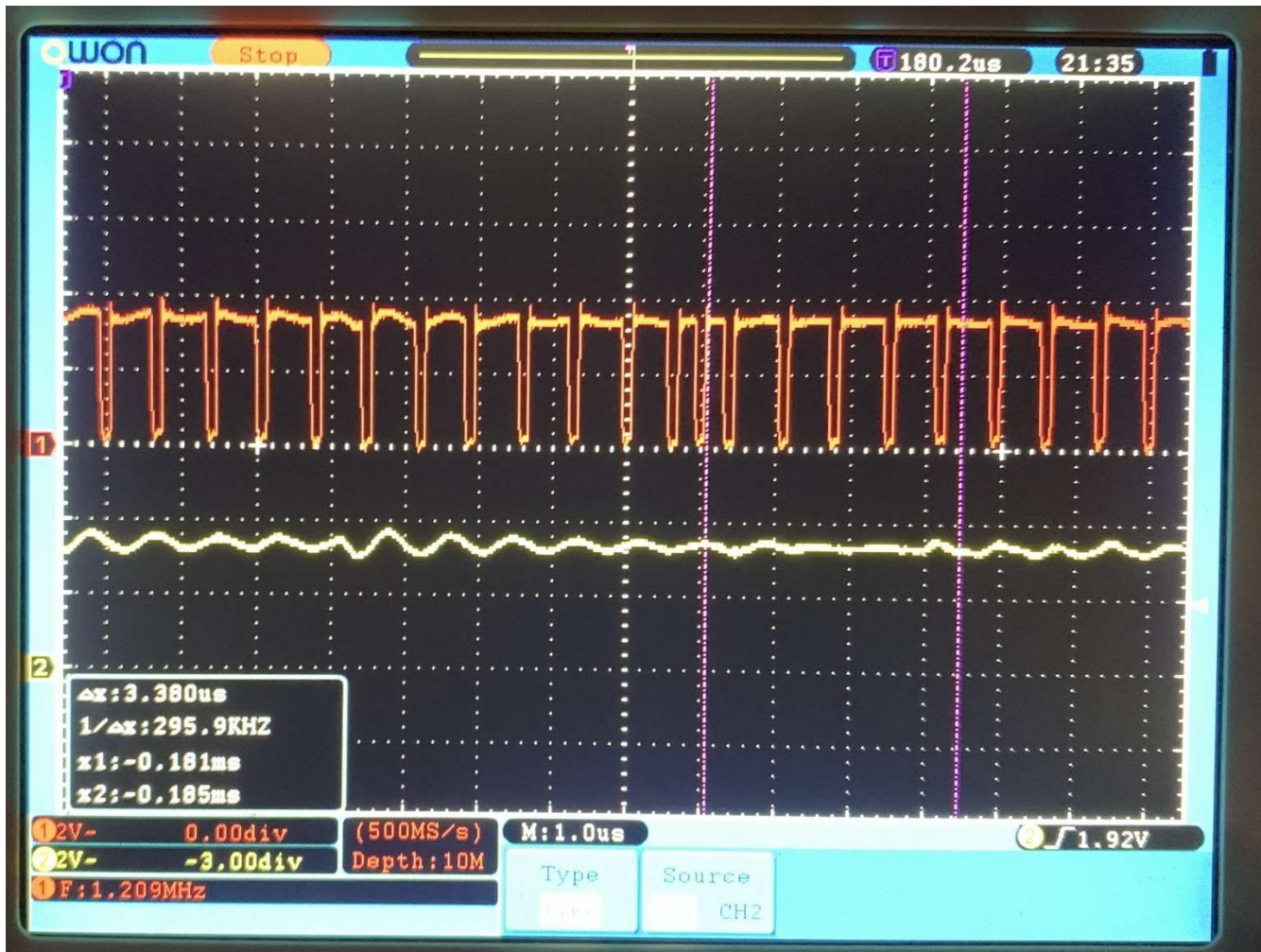
Set up a simple read loop:

```
tester-0>m chs
  Make Cylinder Head Sector list. Enter Cylinder Head Sector parameters
  chs_list>0 0 0
  chs_list>x
List End, 1 items
tester-0>disp chs
  Cylinder Head Sector List
  #   cyl  h  sect
    0,   0, 0,  0
tester-0>read loop
  Read Loop test. Hit any key to stop the loop.
  list_item = 0
  list_item = 0
### ERROR, read command time exceeded in write_loop_zero reading data, testing
tester-0>
```

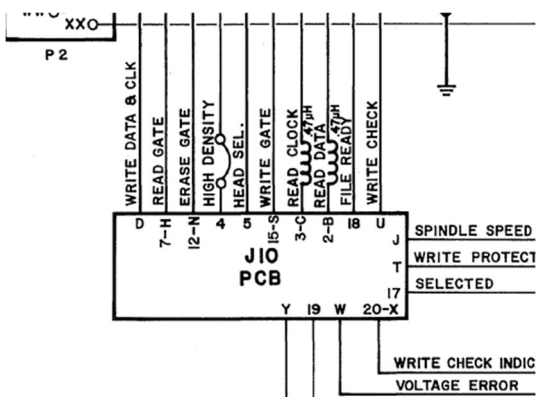
But even with the read command time exceeded error, the read gate is still active so the read data and clock signals can be probed.



Read Clock is CH1 and Read Data is CH2. It appears that the data pulses are still present in the read clock, and data isn't being separated onto Read Data as it should be. The bit rate appears to be about 1.44 Mbps.



Trace Read Clock back from J10-3-C and Read Data back from J10-2-B.



On J10, TP3 looks like red trace above; TP4 always high; TP5 always low

The schematic of the data recovery circuit on J10:



**March 13, 2025**

Cut the leg of F37 pin 6, the Q-bar output of the DM8601 retriggerable one-shot. Connected a jumper from F37 pin 8 (the Q output of the one-shot) to K74 pin 13 (input of the spare inverter). Connected a second jumper from K74 pin 12 (output of the spare inverter) to the pad beneath F37 pin 6 (where the Q-bar output of the one-shot was connected before the pin was cut). This is a temporary work-around until the replacment DM8601 arrives.

After this temporary fix, clock and data appear to be correct, with a stream of periodic clock pulses and data pulses that appear in the center between the clock pulses:



...and the data rate appears to be about 1.4 Mbps

Next step: attempt to read the disk cartridge using the Tester. Entered the Disk Read command

```
tester-0>disk read d2315.rke
  External Disk Read Image.
  external drive is ready
  microSD card is present
  filesystem started
  microSD LED is on
  opening the disk image file
  file_open_write_disk_image_n 'D2315.RKE'
sd_spi_go_low_frequency: Actual frequency: 398089
V2-Version Card
R3/R7: 0x1aa
R3/R7: 0xff8000
R3/R7: 0x80ff8000
Card Initialized: Standard Capacity Card: Version 2.x
SD card initialized
Standard Capacity: c_size: 239
Sectors: 0x3c000 : 245760
Capacity: 0x7800000 : 120 MB
sd_spi_go_high_frequency: Actual frequency: 12500000
filename = D2315.RKE
  writing the file header
  Writing header to file 'D2315.RKE'
  Reading external disk data
    cylinder = 0
    cylinder = 20
    cylinder = 40
    cylinder = 60
    cylinder = 80
    cylinder = 100
    cylinder = 120
    cylinder = 140
    cylinder = 160
    cylinder = 180
    cylinder = 200
  Reading data from disk is complete.
  Writing external disk data to microSD.
  Writing disk image data to file 'D2315.RKE':
  cylinders=203, heads=2, sectors=16
    cylinder = 0
    cylinder = 20
    cylinder = 40
    cylinder = 60
    cylinder = 80
    cylinder = 100
    cylinder = 120
    cylinder = 140
    cylinder = 160
    cylinder = 180
    cylinder = 200
  writing image to microSD is complete
  Closing the microSD file.
  Closing the microSD file is complete
  The entire operation is complete
tester-0>
```



Made a backup of D2315.rke and copied it to another microSD card that was inserted into an emulator attached to the PDP-8/m. PDP-8/m has two emulators connected to its RK8-E. Drive 0 has a known good OS-8 image and drive 1 has the newly created D2315.RKE file.

RKB0: has a valid PDP-8 OS-8 directory and 71 files. However a entering DIR RKB1: produces:

```
.DIR RKB1:  
BAD INPUT DIRECTORY
```

Wrote the OS8 image onto the 2315 disk cartridge using the Tester disk write command:

```
tester-0>disk write os8.rke
```

Then connected the Diablo drive to the PDP-8. Connected through the emulator on the right which is not loaded and set to drive 1. This emulator is only a pass-through for the disk signals. The Diablo drive is configured as drive 0. So, the Diablo is the only drive connected to the RK8-E controller in the PDP-8.



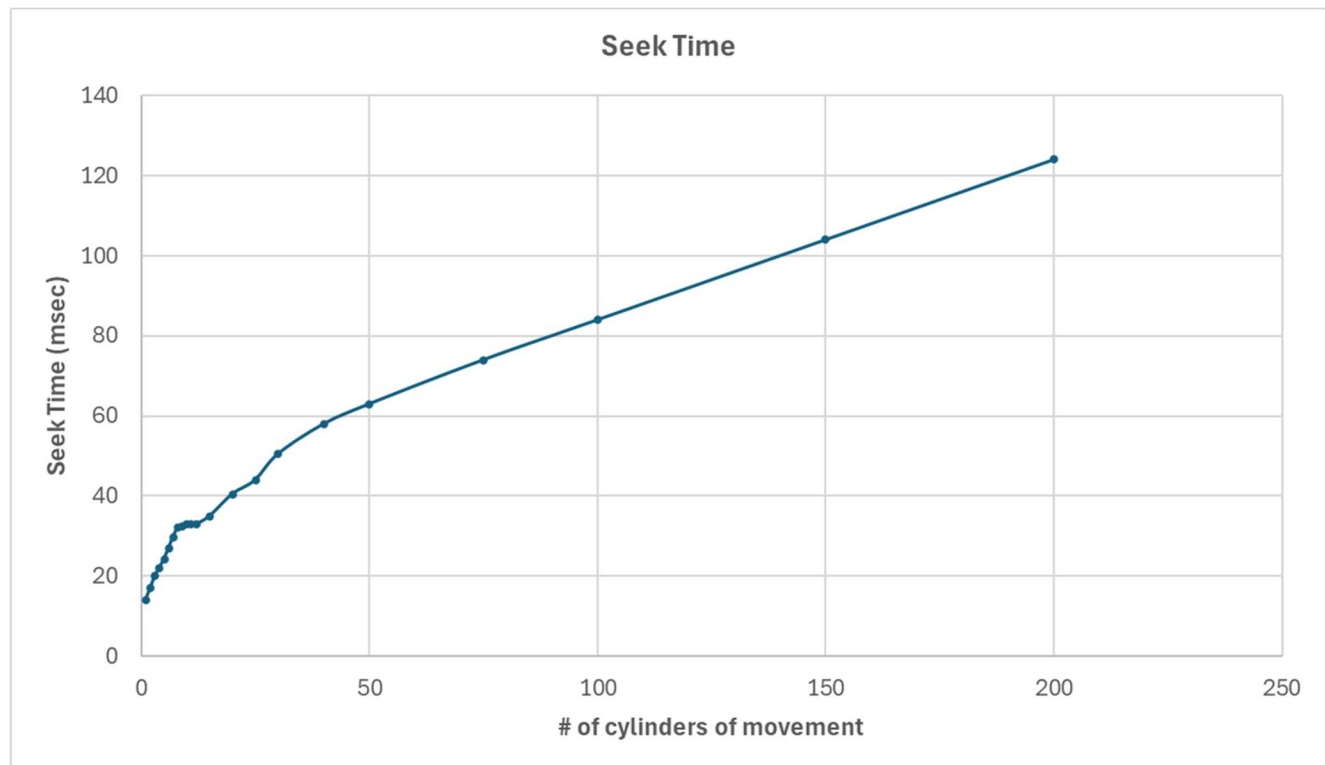
Was able to boot OS8 from the Diablo drive!

Still need to properly repair the board in J10. A pair of DM8601 one-shot ICs are on order. Need to replace the one at location F37 on the J10 board and remove the temporary jumpers.

**March 14, 2025**

There's still a problem with the drive. When running the `write loop random` test, there are occasional errors. Discovered that when seeking more than about 20 sectors (it seems to vary) then there are intermittent errors in the `write loop verify` test. The CHS list contained: 0 0 0, 20 0 0.

Collected data on the time when RWS ready is inactive after a seek operation, `w l n` command:

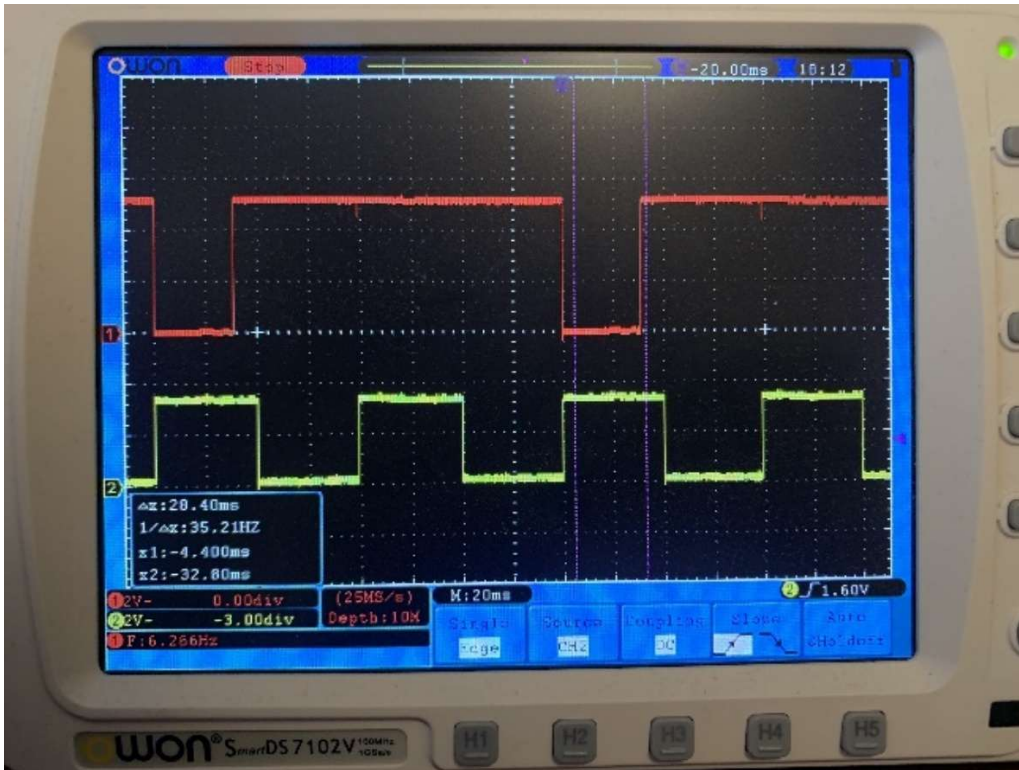




March 15, 2025

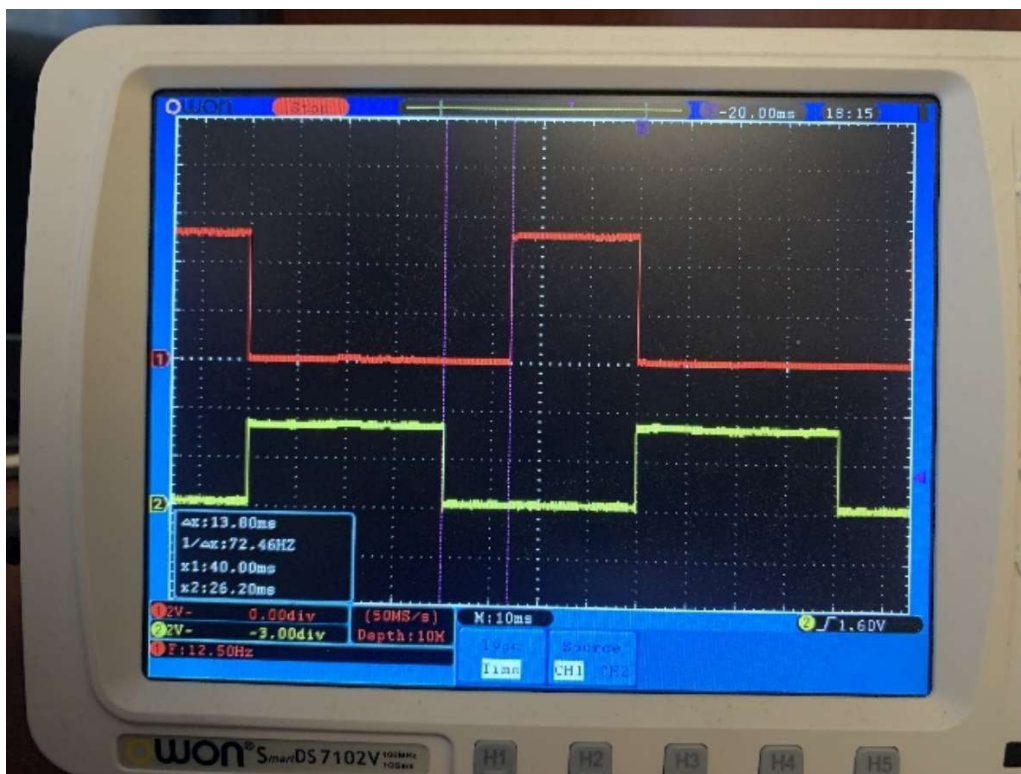
Observe the test points on module J2 in the digital circuit related to head movement. Entered a CHS list containing: 0 0 0, 20 0 0. CH1 (red) is TPx, CH2 (yellow) is BUS\_RWS\_RDY\_L (pin F on the MRAC42):

- TP1 – always high, low sets the “SEEK INCOMPLETE FF”
- TP2 – always high, “RESTORE FF1-Q-bar”
- TP3 – same as RWS Ready, “-R/S/R/W”
- TP4 – “-REV & 1<sup>st</sup> SPEED”



- TP5 – always high, “INITIAL RESET”

- TP6 – active-low “Motion Indicator Level”

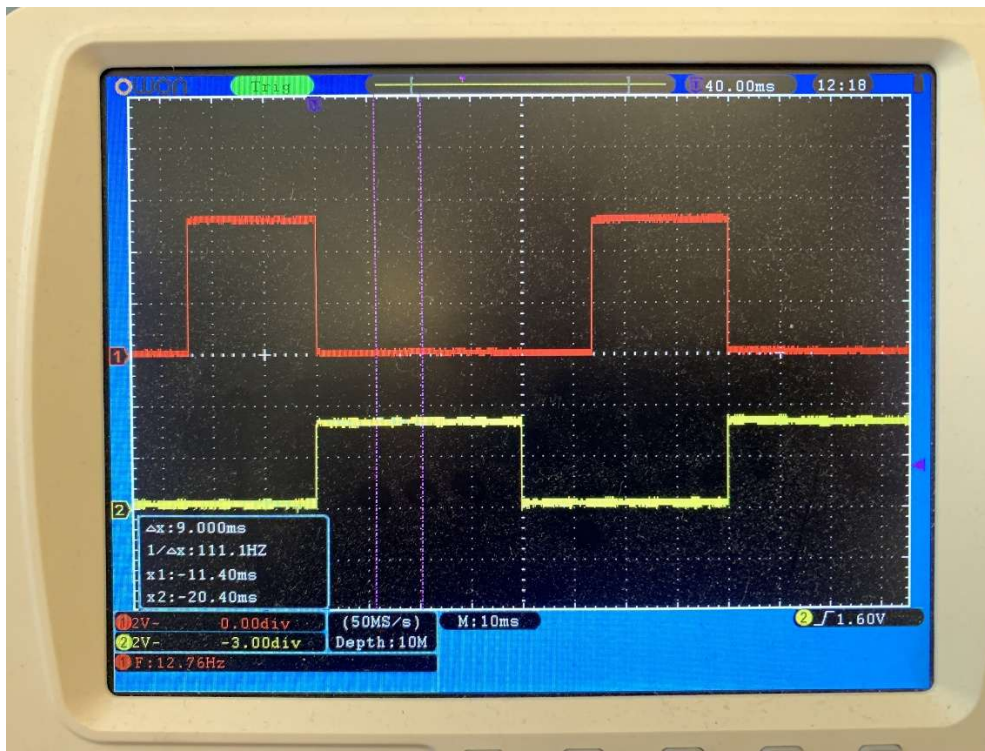


- TP7 –



March 16, 2025

Motion Indicator Level signal, module J2 TP6:



In the last paragraph in section 4.6: “The remaining circuit on the J1 PCB is the Motion Indicator Level, which gives a low output at pins 14 and R only when the positioner has been stationary for the preceding 30 milliseconds. This signal is used to detect motion or the lack of motion during a Seek or Restore Operation.”

The signal shown in CH1 (red) above is the inverted Motion Indicator Level signal.

**March 17, 2025**

Connected the Diablo Model 31 to the RK8-E in the PDP-8/m, and ran "maindec-08-dhrkc-h-pb". The following group of 3 Write Status Errors and one Non-recoverable Write Status Error repeated 6 times, followed by the Recalibrate Status Error at the end:

```
WRITE STATUS ERROR
PC:2347 ST:4001 EX:0000 CM:4530
IA:5772 DA:5772 CA:0141 WC:4200 FW:4400

WRITE STATUS ERROR
PC:2347 ST:4001 EX:0000 CM:4530
IA:5772 DA:5772 CA:0141 WC:4200 FW:4400

WRITE STATUS ERROR
PC:2347 ST:4001 EX:0000 CM:4530
IA:5772 DA:5772 CA:0141 WC:4200 FW:4400

NON-RECOVERABLE WRITE STATUS ERROR
PC:2347 ST:4001 EX:0000 CM:4530
IA:5772 DA:5772 CA:0141 WC:4200 FW:4400

RECALIBRATE STATUS ERROR
PC:3113 ST:6040 EX:0000 CM:0000
DA:5772

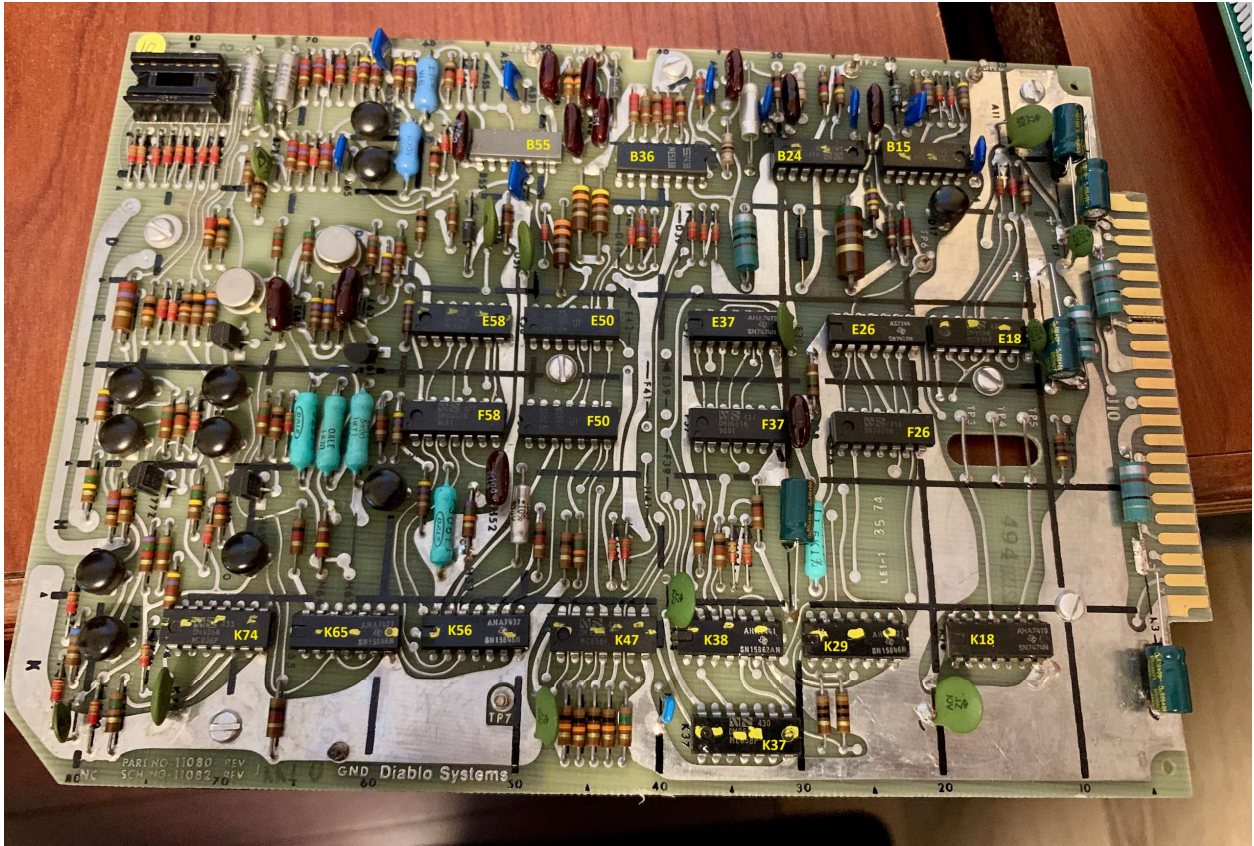
RECALIBRATE ERROR DISCONNECT!
DISK 0 DISCONNECTED!
```

Before running this test with the Diablo I confirmed that the same maindec ran fine when the RK05 Emulator was attached to the 8/m.



### Afterthoughts:

- I thought about designing an extender board to be able to more easily probe circuits on the six plug-in cards. The extender would need to offset in one direction to have mechanical clearance from the frame of the disk drive. Fortunately, most of the probing was on J10, which is on the end of the backplane, on the left side of the drive. It was possible to remove the metal shield from the J10 board to be able to probe circuitry from the back.



- The Tester command read loop was very convenient for debugging the fault in the data separator circuit.

tester-0>m chs

Make Cylinder Head Sector list. Enter Cylinder Head Sector parameters

chs\_list>0 0 0

chs\_list>x

List End, 1 items

tester-0>disp chs

Cylinder Head Sector List

# cyl h sect

0, 0, 0, 0

tester-0>read loop

- x