HP65 Diagnosis and Repair

This article describes some steps to determine if a HP65 calculator is possibly repairable. This article is not a complete diagnosis and repair guide, although as you follow this guide, you will inherently be repairing the calculator anyway. This guide is a side effect of me trying to determine if two HP65s I bought were repairable. There might be more to come later, but for now hopefully you will find this instalment useful.

John Robinson
(Sometime in the 21st century)

What you will need

- Multi-meter
- Soldering Iron, solder etc
- De-soldering equipment, Hakko style preferred
- 3.6 - 4.5 V DC power supply (3 x AA batteries, NiCd or NiMH preferred) battery pack.
- Oscilloscope with at least 1MHz bandwidth
- Various pieces of wire, sticky labels etc.
- 14 pin and 16 pin IC test clip

1. Step 1 – Read Tony Duell's article on the www.hpmuseum.org website Tony has a good in depth knowledge of the HP65 (and other calculators), and provided me with lots of help when doing my diagnosis.

Precaution : Never insert or remove the logic board, and/or card reader boards while power is on.

Prepare the calculator

Disassemble the calculator and remove it from the case, and unsolder the card reader and remove it. The card reader is probably the least of your worries, so repairing that will come later (maybe). It's a good idea to separate the logic board from the display/keyboard, and give the boards a clean with a good circuit board cleaner and tooth brush, and there may be corrosion or other contaminants present from leaking batteries etc.

Since the calculator is now out of the case, the power switch is inoperable, so solder a wire to short the power switch, but don't solder it on the switch contacts themselves. See Figure 1, blue wire.

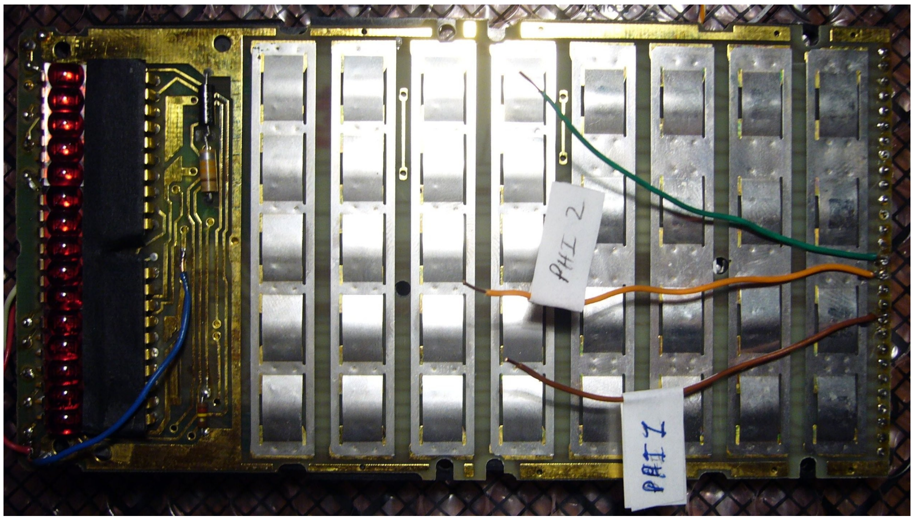


Figure 1

Also, power from the battery reaching the calculator relies on the piece of metal from the charger socket making good contact between the two outer pins. This piece of metal has probably fallen out when you disassembled the calculator. You should short the two outer connections on the charger socket to make good contact, see Figure 2.

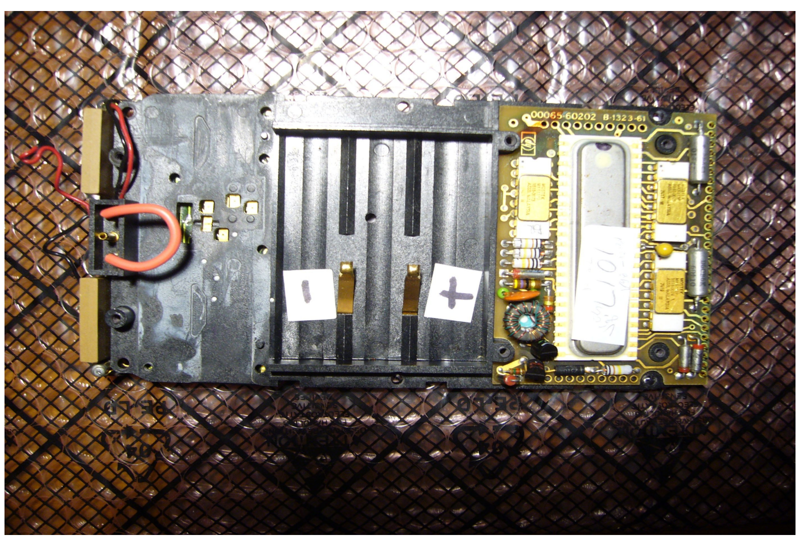


Figure 2

It’s a good idea to label the pins of the 28 pin connector at the bottom of the display/keyboard. I printed out the pin listing from Tony’s article in 8pt font, and sticky taped it onto the key side of the display/keyboard. See Figure 3.

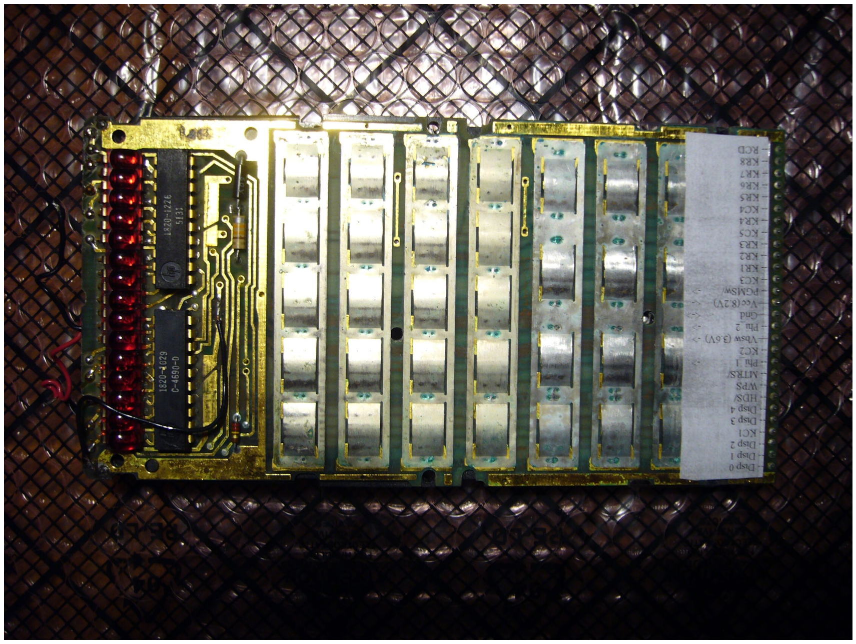


Figure 3

I also like to label the battery terminals with a “+” and “-“ stickers so I don’t get confused, the positive is the lower terminal, See Figure 2.

Before we finish with preparation, a handy tip (thanks to Dan Weed, is that you “flip” the logic board over, as per Figure 4.

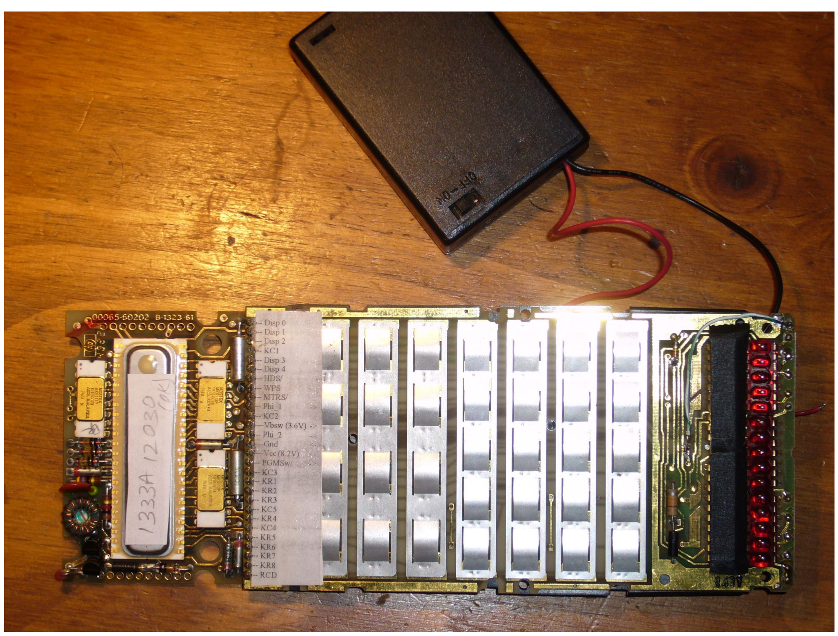


Figure 4

Flipping the logic board over will allow access to the underside of the logic board for testing voltages and signals.

Power Supply

Checking the Power Supply operation

As you now know from reading Tony Duell's article, most of the power supply components are located on the HP65 logic board, however power from the battery arrives at the logic board via the display/keyboard. Even the display driver chips on the display/keyboard are powered from the logic board.

The HP65 power supply is one of the more repairable sections of the calculator circuitry, and is commonly known to fail. Given that, it is worth while spending the time to get the power supply functioning correctly, as without a correctly functioning power supply, the calculator will not function at all.

Again, as you know from Tony's article, the power supply takes the battery voltage, and from that battery voltage, generates the three voltages that are required by the calculator Vcc, Vss and Vgg.

Figure 5 is a drawing of the power supply circuit.

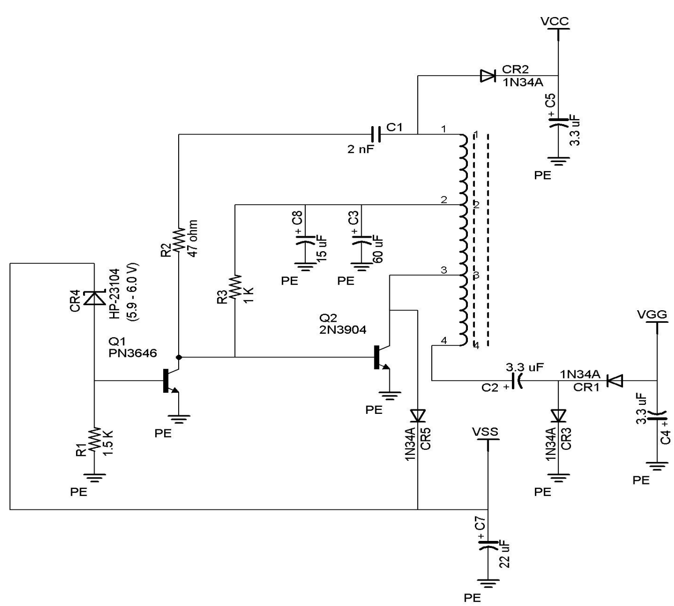


Figure 5

Figure 6 illustrates the location of the various logic board components including the power supply components, which are highlighted in red. Note that C6 is not part of the power supply.

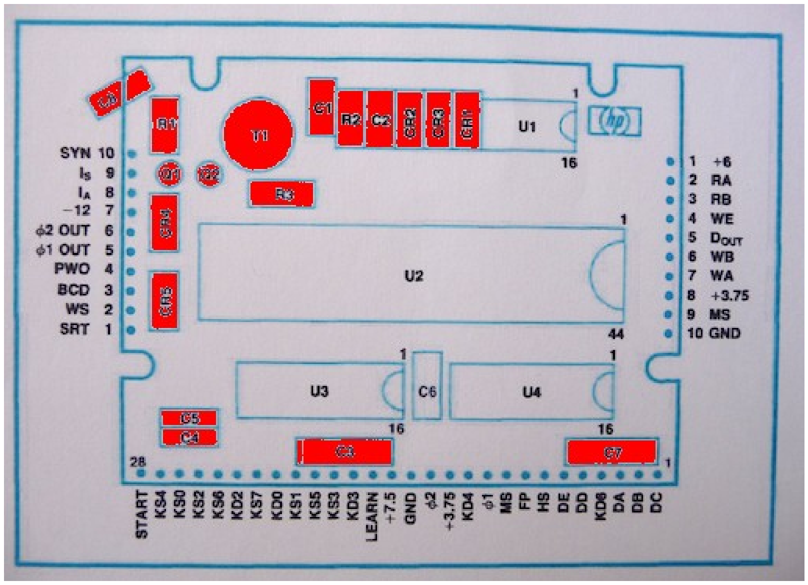


Figure 6

To test the correct operation of the power supply, it's best to test it disconnected from the rest of the calculator circuitry. To do this, you will need to disconnect each of the three voltages Vcc, Vss and Vgg from the calculator circuitry. Figure 7 illustrates where these voltage outputs are to be disconnected.

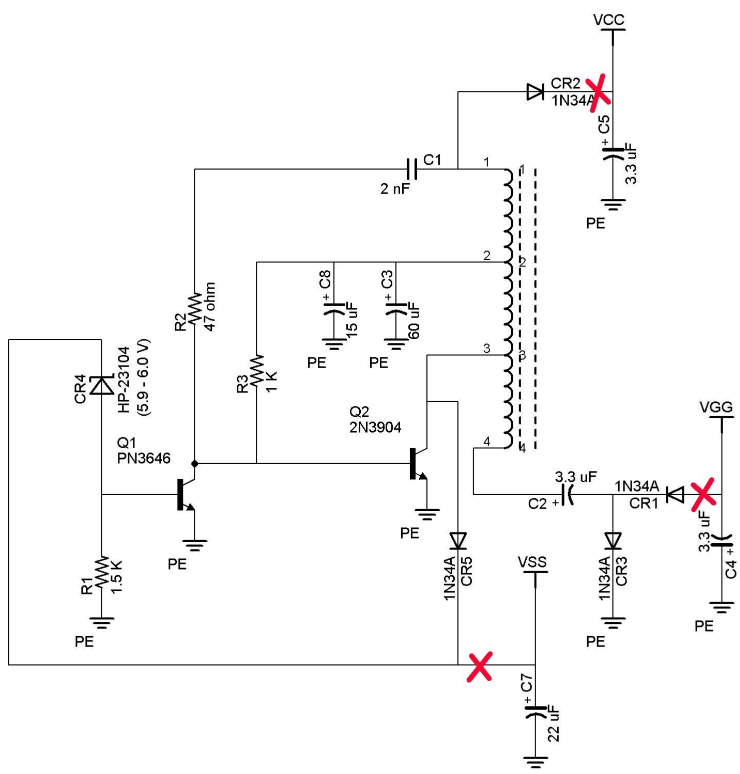


Figure 7

Disconnecting Vcc and Vgg are quite easy, and figure 8 shows a circuit where cathode of CR2 and the anode of CR1 are de-soldered and lifted up out of the circuit board.

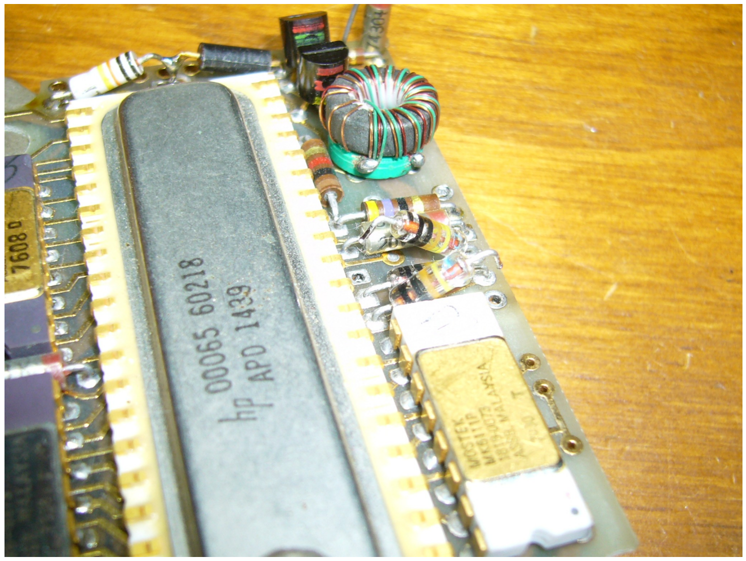


Figure 8

Disconnecting Vss is a little more difficult, and the connection between CR4 and CR5 needs to remain. By de-soldering the cathode of CR4 and the cathode of CR5 from the logic board, and lifting them up, it's possible to solder them together without being connected to the circuit board. See figure 9.

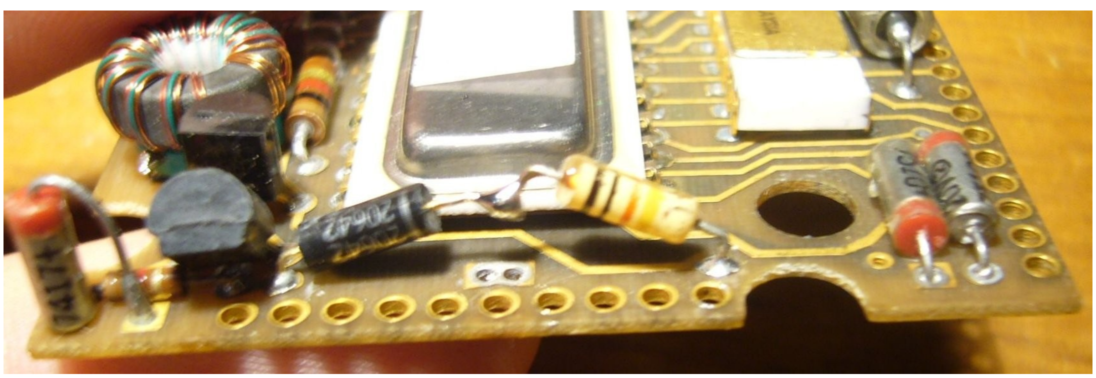


Figure 9

The connection between the cathodes of CR4 and CR5 is Vss.

Vbsw : Now, with the logic board removed, apply the power to the battery contacts. You should be able to measure the battery voltage between Vbsw and Gnd on the 28 pin connector. Disconnect the power from the battery contacts.

Vcc : Vcc (along with Vss and Vgg)is generated on the logic board from the Vbsw supplied from the display/keyboard. With the power disconnected from the battery contacts, measure the resistance between Vcc and Gnd on the display/keyboard, this should measure about 200K ohms. This is all you can do with the logic board removed, so now install the logic board, and connect power to the battery contacts.

Measure Vbsw again to make sure it hasn't dropped too far below the original value. Also, measure the voltage at pin 2 of T1 to check if it is the same as Vbsw. Now measure Vcc, Vss and Vgg.

Vcc should be just around 8.2V.

Vgg should be about -12.4V

Vss should be about 6.28V

If all these three voltages, Vcc, Vss and Vgg are correct, then they can be reconnected to the logic board, but before doing that, it is wise to check the resistance of the load on each of these from the remainder of the calculator electronics. The load should be approximately :

Vcc : > 10 Mohm
Vss : ~ 1 Mohm
Vgg : > 10 Mohm

If you measure similar load resistances for all three, then reconnect Vcc, Vss and Vgg to the logic board by resoldering the cathode of CR2 and the anode of CR1, and the cathodes of CR4 and CR5 to the logic circuit board. Retest all three voltages, and if all is still good, then you may move to the section on reset.

If any of Vcc, Vgg or Vss are not close to the quoted values, you will need to repair the power supply circuitry on the logic board.

Repairing the Power Supply

The Power Supply is a DC-DC converter based on a blocking oscillator circuit. For an excellent description of the theory of operation, see the website: http://www.jacques-laporte.org/HP35%20power%20unit.htm of Jacques La Porte. A description of the theory of operation will not be given here. There are several possibly causes of failure of the power supply, but we will start here assuming that none of the power supply output voltages (Vcc, Vss and Vgg) are correct.

Along with the basic (blocking) oscillator (Q2 and surrounding components), the power supply also includes components which regulate the output voltage (Q1 and surrounding components), and components to rectify and filter the three output voltages.

Oscillation

The first step is to see if the oscillator is oscillating. To do this, apply power to the battery contacts, and with an oscilloscope, examine the signal present at pin 1 or T1, the "pulse transformer" or coil, or the signal at the base of Q2.

The waveform which should be present at pin 1 of T1 is shown in figure

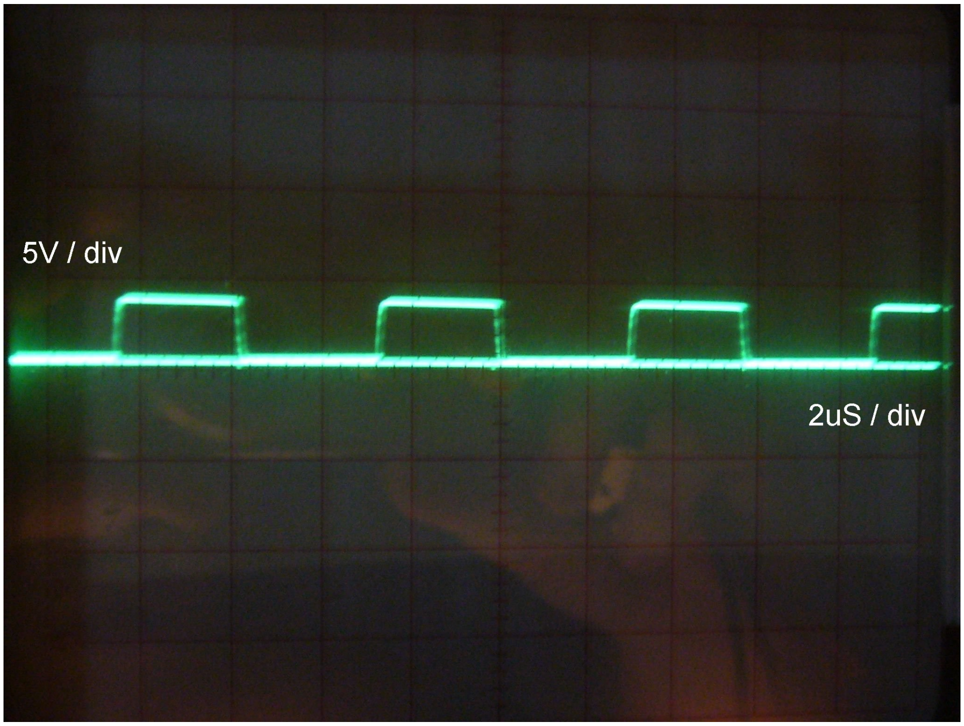


Figure 10

This waveform has a frequency of around 180Khz and Peak to Peak voltage of about the same as Vbsw.

If this signal is not present, then the basic oscillator is not oscillating. The only components required for the basic oscillator are shown in figure 11. To test these components alone, disconnect the regulating circuit by removing Q1, and again test for the signal shown in Figure 10 at pin 1 of T1. If the signal is now present, then proceed to the section on Voltage Regulation.

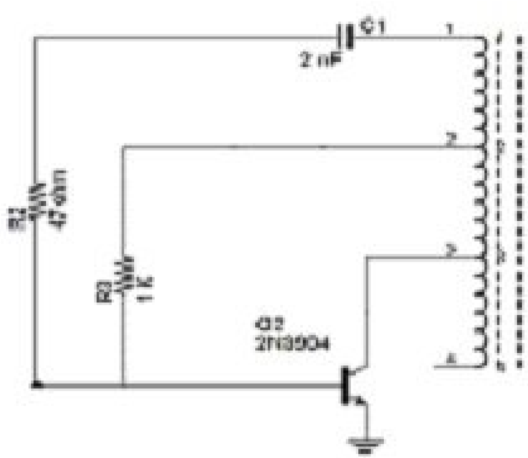


Figure 11

The five components shown in figure 11 are all the components required to form the basic blocking oscillator. These five components are highlighted in figure 9 by the red box.

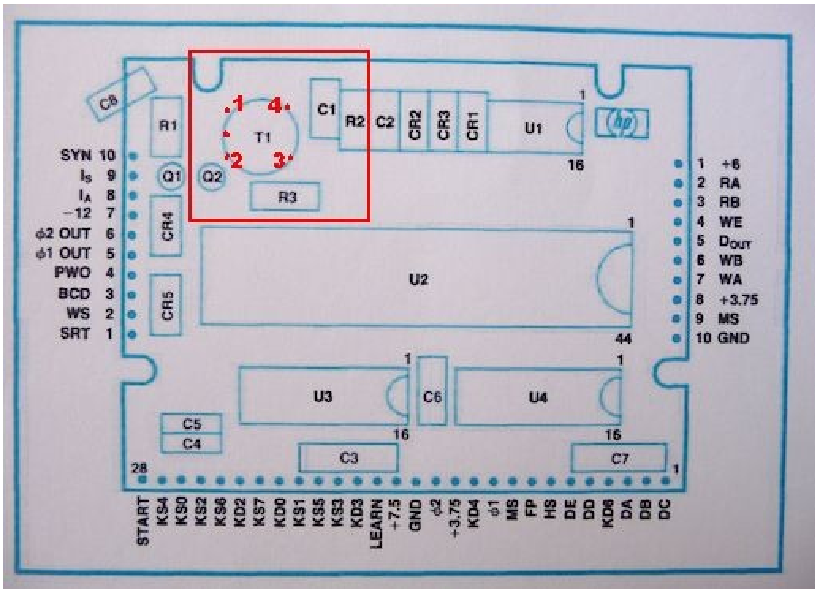


Figure 12

Remove C3, C8 and C2, the remaining components in the oscillator circuit are those shown in figure 11. Although the tantalum (silver coloured) capacitors used on the logic board are high quality Kemet brand capacitors which should still function correctly, a 40 year old capacitor is suspect when a circuit is not functioning correctly. Again test for the signal shown in Figure 10 at pin 1 of T1. If the signal is now present, then proceed to the section on Voltage Regulation.

With the five component basic oscillator not functioning, the component mostly likely to be fault is Q2. The next mostly likely components to be faulty are C1 and T1. Replace Q2 with a new transistor, 2N3904 and replace C1 with a 2nF polyester capacitor. T1 is difficult to replace unless you have a spare, probably from a donor calculator. If you do have a spare, then replace that as well.

With these components replaced, again check the signal at pin 1 on T1, which should look like that shown in figure 13 below. If that signal is present, then you may move to the section called Rebuilding the Power Supply.

Although unlikely, T1 could be faulty if you have not replaced it with a known good transformer. To check T1, I would recommend removing T1 from the logic board, and building the basic oscillator on breadboard using a new 2N3904 for Q2, a new 2nF capacitor, new resistors and the transformer. The circuit to build is shown in figure 11, and then with the circuit built, measure the signal at pin 1 of T1. This signal should look like that shown in figure 13.

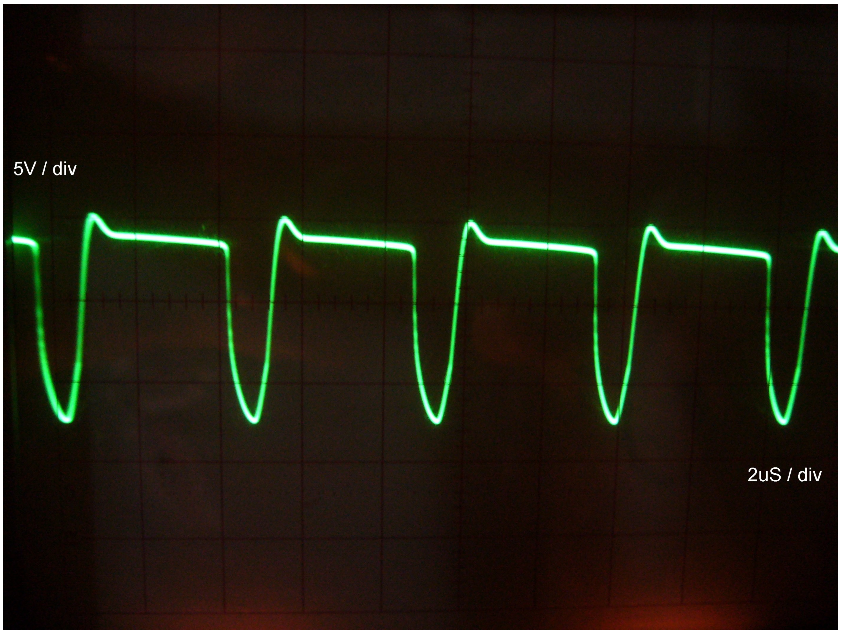


Figure 13

Also, with the components currently removed from the circuit board, visually inspect the circuit board pads where these components are normally installed, and the interconnecting tracks. You may also want to check for continuity between the component pads. If the circuit board appears to be fine, then re-install the components used to build the basic oscillator on the breadboard. If you still do not observe an oscillating signal at pin 1 of T1 then I have no further suggestions for you. If you do now observe oscillating signal at pin 1 of T1 then move to the section called "Voltage Regulation"

Voltage Regulation

With the power supply's basic oscillator now verified to be functioning, it's time to look at the Voltage Regulation components. Vss is the voltage which is used to compare with the reference voltage of CR4 (Reverse biased) and CR5 (forward biased). The base of Q1 is biased to control the frequency of the oscillator.

Currently, Q1 is removed from the circuit board. Install a new 2N3646 transistor for Q1, along with R1, CR4 and CR5, but with CR4 and CR5 connected "off board" as shown in figure 9. Measure the voltage across R1, which should be around 0.7V.

Measure Vss with a DC voltmeter, it should be around X.XV. If the correct voltage is measured for Vss, the voltage regulation components are functioning correctly. If Vss is not measured at the correct level, CR4 is suspect and should be replaced.

Rectification and Filtering

All three voltages, Vss, Vcc and Vgg are subject to rectification with half wave rectifiers and some filtering with capacitors.

Vcc is rectified by CR2 and filtered by C5
Vss is rectified by CR5 and filtered by C7
Vgg is rectified by CR1 and filtered by C4

Vss has the largest filter capacitor of 22uF as compared to Vcc and Vgg having filter capacitors of only 3.3uF. I suspect this because Vss is uses as the comparison voltage for the voltage regulation components.

Now, install C2, CR3, and CR1, but leave the anode of CR1 disconnected. Likewise, install CR2, but leave the cathode disconnected as shown in figure 8.

Measure Vcc and Vgg with a DC voltmeter, they should measure close to the quoted values above for a good power supply.

Reset

Init C and Init need to be checked for correct operation. Init C should go to about 0.8V upon power up, and Init should go to about 6V on power up.

Init can be tested at the test point, and should be just over 6V.

If either of these voltages are not present, then replace C6.

Timing Signals

Phi_1 and Phi_2

Now that you have the correct voltages from the power supply, you need to verify that the anode driver chip is generating Phi_1 and Phi_2 correctly. Figure 14 shows Phi_1 and Phi_2.

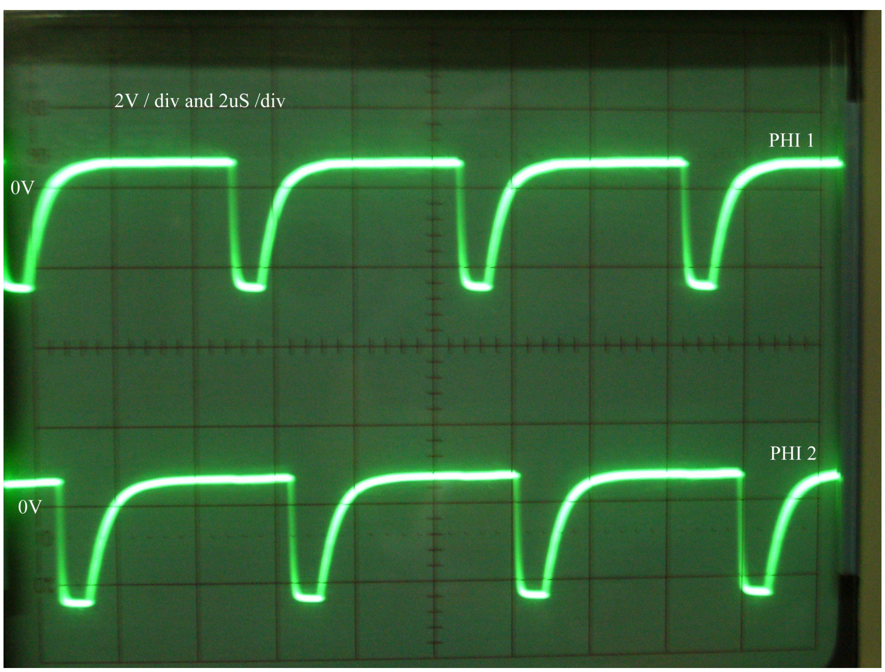


Figure 14

If you do no have good Phi_1 and Phi_2 signals, you will need to repair the display/keyboard. See the section Anode Drivers Signals.

Phi_1_out and Phi_2_out

With good Phi_1 and Phi_2, Now check that the Hybrid CPU chip is generating Phi_1_out and Phi_2_out correctly. Figure 15 shows Phi_1 and Phi_1_out.

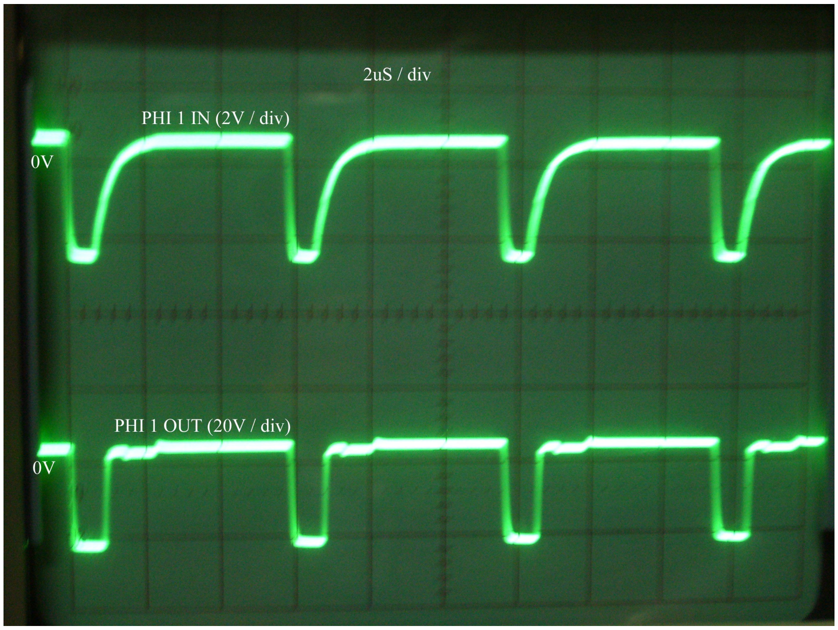


Figure 15

For Phi In/Out comparison, Figure 16 shows Phi_1 and Phi_1_out.

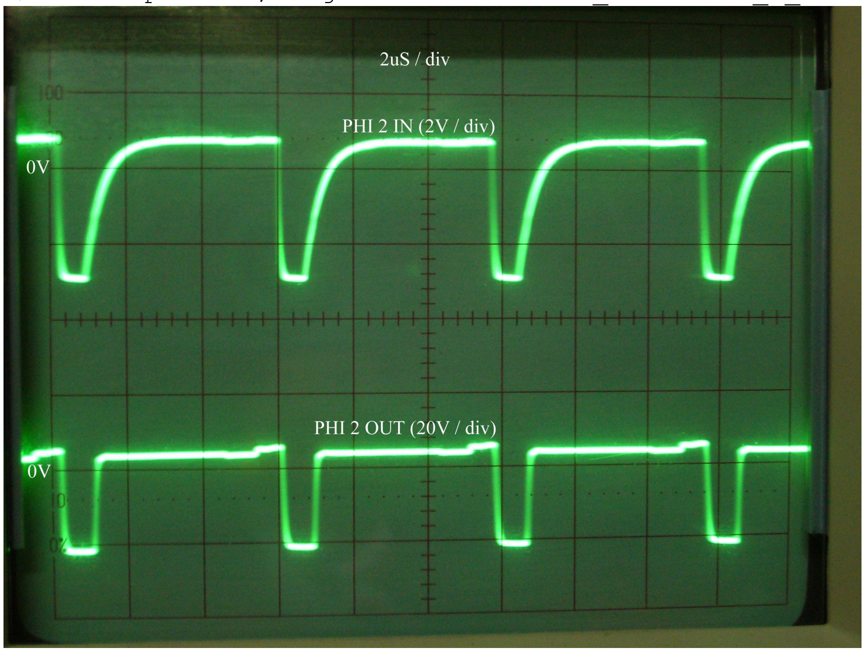


Figure 16

Sync and Data

Now check that the Hybrid CPU chip is generating Sync correctly. Figure 17 shows Sync (and Data) signals.

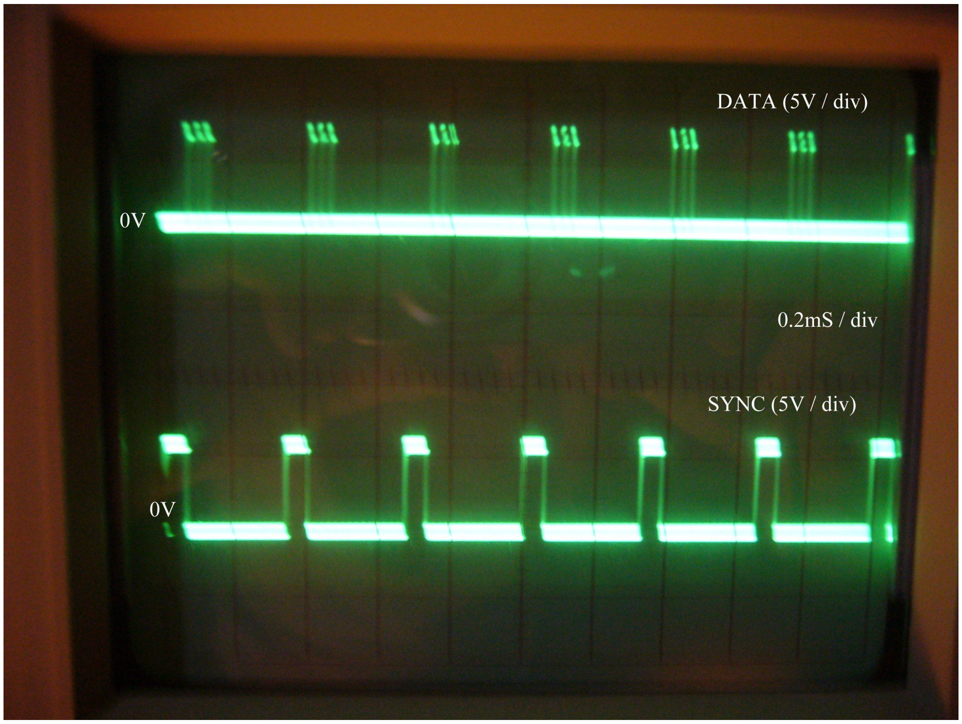


Figure 17

If the Phi_1 and Phi_2 in and out signals are correct, and the Sync signal is correct, check the Data signal has activity as shown in figure 17 as well, but it may not look exactly like that show here. The signal shown in figure 17 is the Data signal with the calculator showing the “0.00” default display.

IA and IS

Like the Data signal, signals IA and IS should also show some activity, but may not exactly like those shown here in Figures 18 and 19.

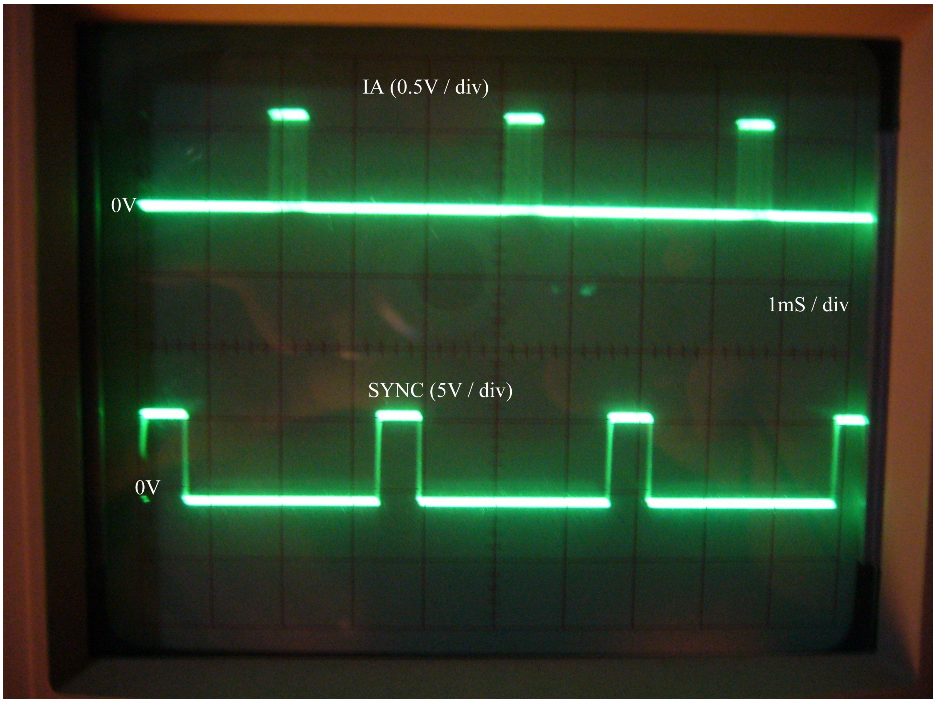


Figure 18

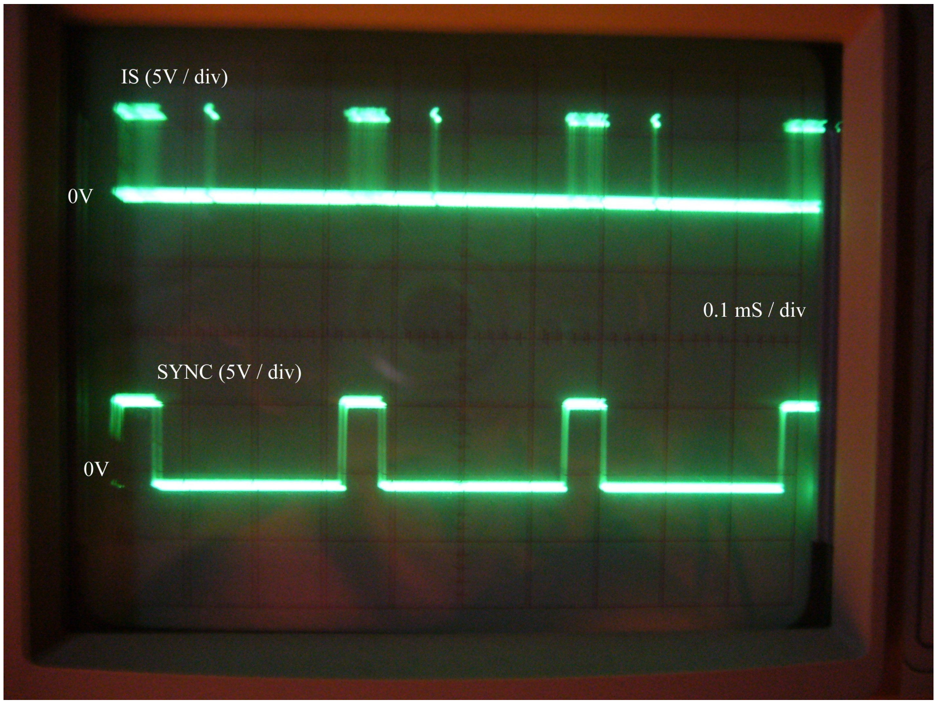


Figure 19

If any of the Data, IA and IS signals do not show any activity, then the Hybrid chip is most likely to me faulty. If that is the case, there really isn’t much that can be done to repair your calculator logic board, apart from replace the board completely.

WS

The next signal to check is WS. WS signal with the calculator in default display “0.00” mode is shown in Figure 20.

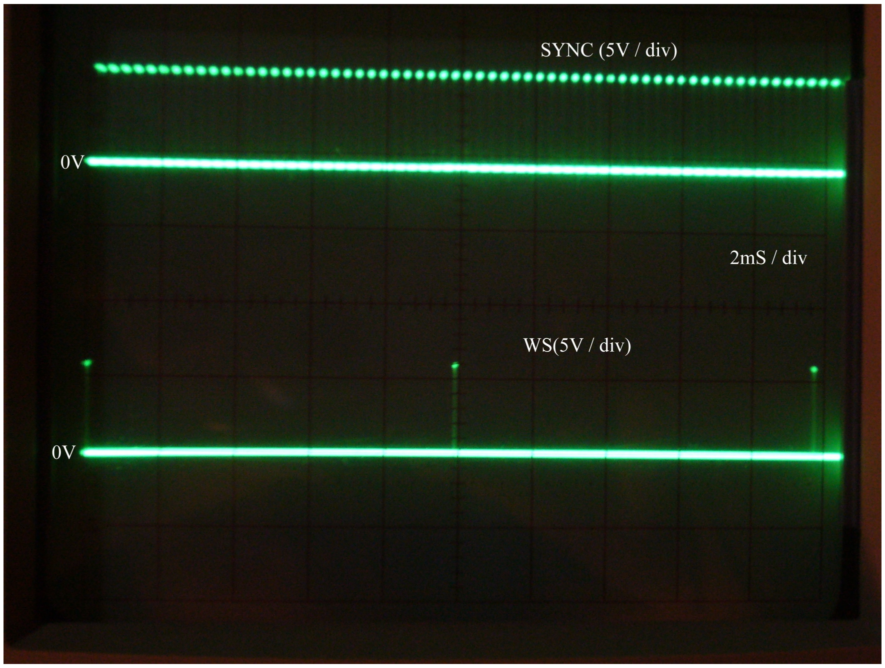


Figure 20

RCD

The final signal to check is RCD (Reset Cathode Driver). RCD is shown in Figure 21 with SYNC.

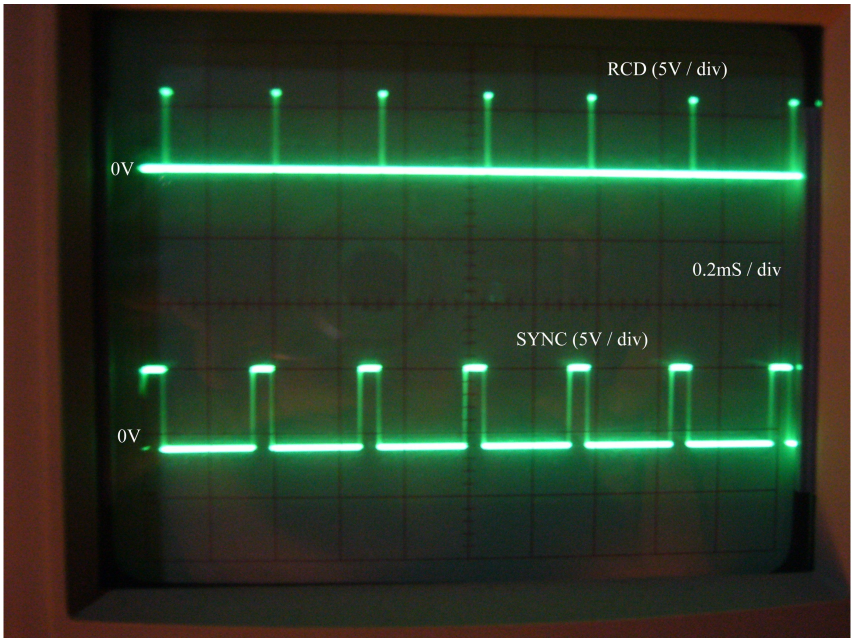
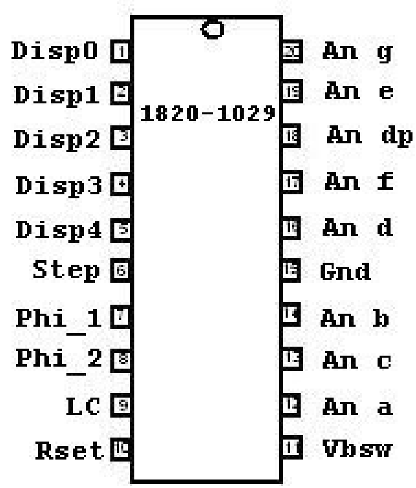


Figure 21

Anode Drivers Signals

Phi_1 and Phi_2 revisited

If Phi_1 or Phi_2 are not being generated correctly, check these signals again at the anode chip. The anode chip is the left side chip near the displays. Figure 14 shows the correct signals for Phi_1 and Phi_2. If the signals are correct at the anode chip pins, then the problem with Phi_1 and Phi_2 is simply a circuit board track connection problem.



1820-1029 (anode driver and system clock)

LC oscillator

Phi_1 and Phi_2 can only be generated correctly if the LC oscillator is functioning. To check the operation of the LC oscillator, check the signal on anode driver pin called "LC". The signal on LC should look like that in figure 22. The frequency of oscillation is around 667Khz.

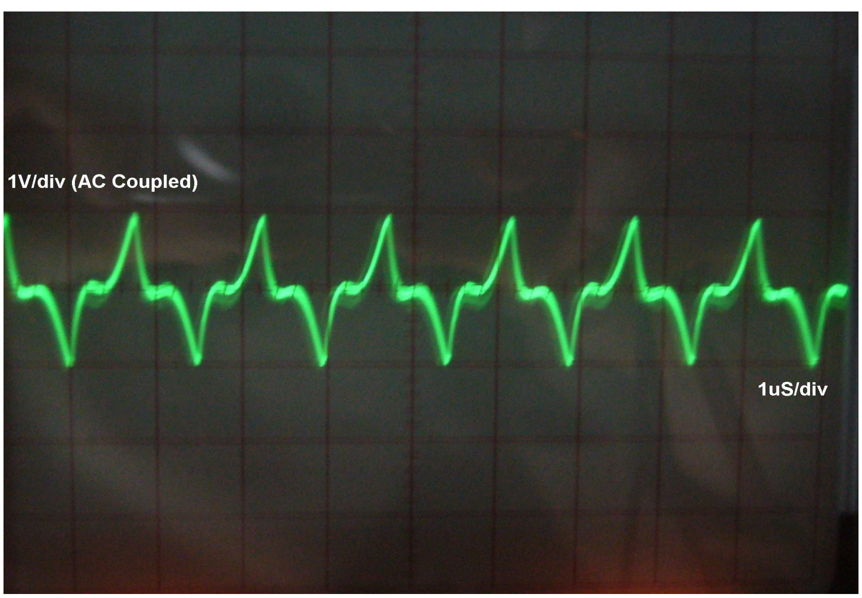


Figure 22

If the LC signal is correct, but Phi_1 and/or Phi_2 are incorrect, then the anode driver will need replacing.

The Display

In the previous sections, you have verified that the power supply is functioning correctly, and the timing signals are all being generated correctly.

The display is driven from the logic board by the Disp0 – 4 signals and the RCD signal. You have already verified the RCD signal is correct. The only other signal of consequence for correct display operation is "Step" which is an output from the anode driver to the cathode driver. The Step signal should look like that shown in figure 23.

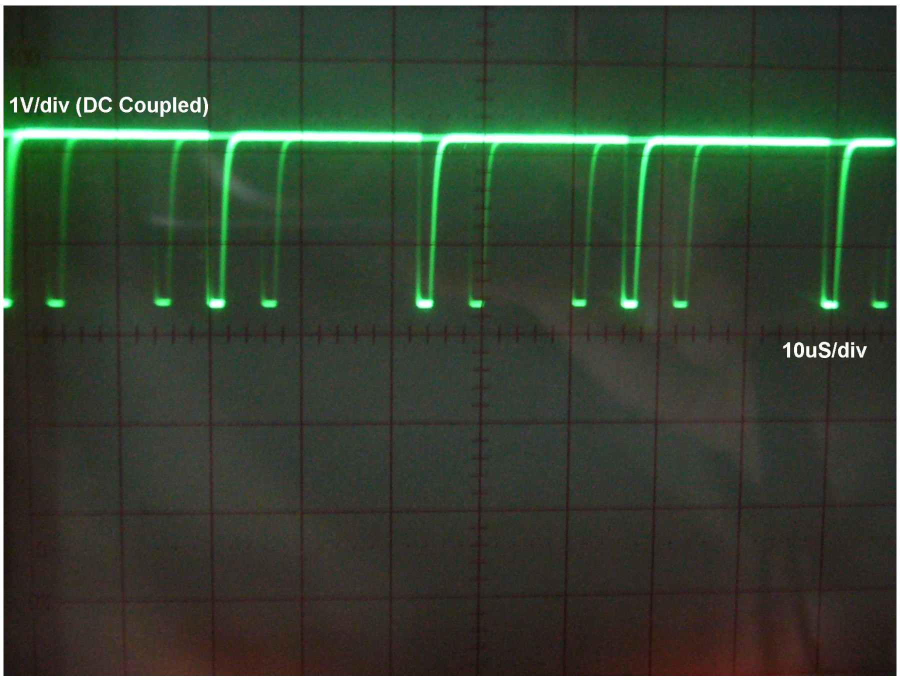
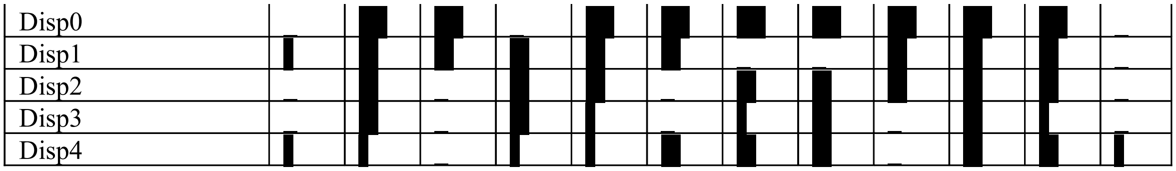


Figure 23

The 15 digits of the display are refreshed about every 320uS, with each digit being refreshed in around 21uS. Each digit of the display can display one of 12 characters, 0 to 9 and . and – being the characters. The character to be displayed in each display position is encoded on Disp0-Disp4 lines, with each character being sent in a serial manner on Disp0-4 with the left most digit sent first.

The encoding of each character on Disp0-4 is done with different width pulses of around 1V in amplitude. There are three different pulse widths used, which are approximately 7uS, 14uS and 21uS.

	-	0	1	2	3	4	5	6	7	8	9	.



Character	Disp0	Disp1	Disp2	Disp3	Disp4
.	-	7uS	-	-	7uS
0	21uS	14uS	14uS	14uS	7uS
1	21uS	14uS	-	-	-
2	-	14uS	14uS	14uS	7uS
3	21uS	14uS	14uS	7uS	7uS
4	21uS	14uS	-	-	14uS
5	21uS	-	14uS	7uS	14uS
6	21uS	-	14uS	14uS	14uS
7	21uS	14uS	14uS	-	-
8	21uS	14uS	14uS	14uS	14uS
9	21uS	14uS	14uS	7uS	14uS
-	-	-	-	-	7uS

If Disp0-4 and RCD signals appear to be correct, then next components to consider are the anode and cathode drivers.

Three display modules used, each module having 5 digits forming a total of 15 digits. These display modules are common cathode type The modules are 14 pin packages, and the pins are identified in figure 24

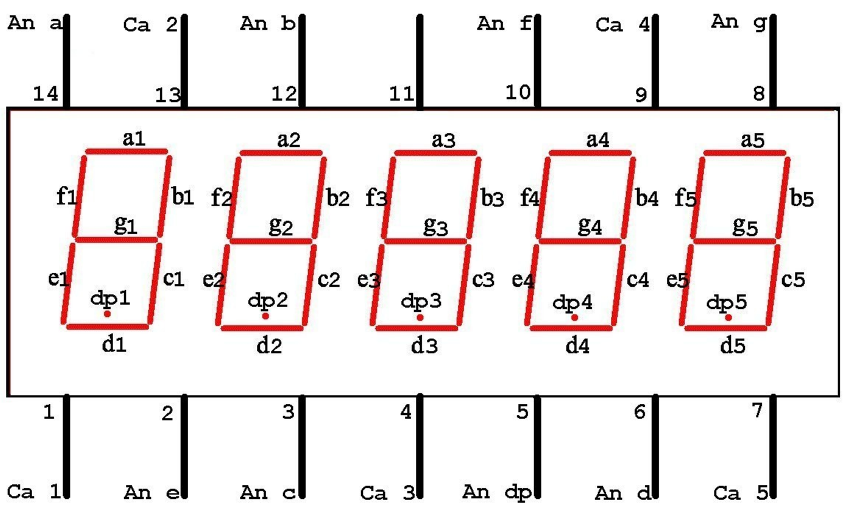


Figure 24

If there is no activity on the display what so ever, it is almost certain that either the anode and/or cathode drivers are faulty, if that is the case, then replace these drivers one at a time until some activity is present on the display.

If all segments from an entire digit are missing, then the cathode driver is likely to be the faulty.

If the same segment from every display digit across all fifteen digits, then the anode driver is likely to be the faulty.

If the same segment from every display within a five digit module but not in all digits across all fifteen digits, then that particular display module is likely to be the faulty.

If there is some activity on the display, but display segments are missing, then the displays themselves could be faulty, or the anode or cathode driver could be partly faulty.

The Keyboard

The keyboard is one of the simpler parts of the calculator to diagnose, although the voltages used for “logic” are rather odd.

KC1-KC5 and KR1-KR8 are the column and row lines for the keyboard. When a key is pressed, one of the KC lines is connected to one of the KR lines. Each of the KC lines is driven to around –12.2V (Vgg perhaps), and each KR line is driven to about +5.9V (Vss perhaps). When a key is pressed one of the KC lines is connected to a KR line, and the voltage on the KC line goes to about –2.5V and the KR line goes to about 2.7V. From the combination of one KC and KR line dropping in voltage, the Hybrid CPU chip determines which key was pressed.

The Card Reader

Bla Bla Bla