**Troubleshooting notes for the HP-150 Touchscreen PCA**

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**Touchscreen operation overview**

The operation of the HP-150 including the touchscreen is described at a high level on page 11 of the August 1984 edition of the HP Journal which can be found at this link.

<http://www.hpl.hp.com/hpjournal/pdfs/IssuePDFs/1984-08.pdf>

I didn’t have access to the schematics of the 150 so have made the following notes from the troubleshooting done when fixing two HP 150s with touchscreen issues.

**Connections to the HP150 processor**

There are only 3 signal lines connecting the touchscreen to the 150 as follows

* The clock line from the 150 to the touchscreen which is used to continually step through each LED to see if there is a finger in the beams. This line can be accessed at Pin 13 of U15.
* The sync line from the touchscreen to the 150 used which is pulsed low when all the LEDs have been scanned by the clock and is used to reset the counter in the 150 scanning firmware code, ready for the next scan. This line can be accessed at Pin 2 of U14.
* The data line which responds to a clock pulse by pulsing low if the path between the led/phototransistor pair is not blocked. This line can be accessed at Pin 13 of U14.

Logic analyser traces of these line in normal (unblocked) operation and one finger detected mode are provided below.

There are also +/-12V and +5 voltage lines in the 10 pin connector on the PCA.

**Observed problems**

A problem with the touchscreen PCA will normally result in a Power on Test 1000 error. Note this error can also be caused by a problem with the keyboard.

The most common problem is a blocked or failed IR LED (CR2-CR36). There are a few ways to detect a failed LED;

* Measure each LED with a multimeter on the ‘diode’ setting. Measure both directions of the LED. If you find an LED that measures differently from the others in either or both directions, that LED is suspect. Typical forward voltage of the IR LED is 1 volt. Measure the phototransistors in a similar way – note I have never seen a bad phototransistor but have seen lots of dead LEDs.
* Another way of checking is to use a digital camera to look at the IR LEDs in operation. Note that an iPhone camera is not sensitive to the 950nm LEDs – find a camera that can detect a TV remote control’s IR LED and use that. You will need to remove the PCA from the 150 bezel and point the camera into the LEDs without breaking the beams. You should see a faint bank of lit LEDs pulsing as the CPU scans the array. If there is an issue with an LED (or matching phototransistor) you will see it as a dark LED in the array or you will see that only part of the array is lit – in which case the bad LED is the first one that is dark.
* Be sure to check for dirt in the LED shrouds, particularly the column LEDs as their shrouds point up and collect dust. Be prepared to wash out the shrouds with isopropyl alcohol and a dentists pick – just blowing air into them may not remove the dust.

Other problems seen that can cause the touchscreen PCA to generate a 1000 error have been;

* Broken traces on the PCA that look OK but have broken where the trace meets a solder pad for a component lead (seen twice)
* Bad 1820-1315 ICs – these 5 ICs take the signals from the phototransistors and are an 8 to 1 multiplexor. I have seen two of these ICs fail by pulling too much current and getting warm. This also had the effect of pulling the voltage down to the rest of the PCA. Check the cathode of Zener diode CR1 – it should be 10.6V approx. Check also the temp of the two 120 ohm resistors near CR1 – they get hot if too much current is being pulled by a bad component.
* Bad 1820-2014 IC – this hex inverter provides chip enable signals to each of the 5 1820-1315s. On the PCA I was working on, one of the 6 inverters was bad and so a whole set of LEDs were not being detected.

**HP part number decode**

Here are some of the part numbers for the ICs and IR LEDs used on the Touchscreen PCA

* 1826-0410 = TL084 Quad Op-Amp
* 1820-0936 = 4024B 7 stage binary counter
* 1820-0939 = 4013B Dual D-Type Flip Flop
* 1820-1315 = 4051B 8 channel analog mux/demux
* 1820-1486 = 4081B Quad 2-Input AND Gate
* 1820-1735 = 74C42 BCD to Decimal Decoder
* 1820-1932 = 4538B Dual Precision Monostable
* 1820-2014 = 4069B Hex Inverter
* IR LEDs CR2-CR36 = IRL80A 950nm infrared LED, side angle.



The traces above are for a normal, working touchscreen with no blockage/finger in the array. The sync pulse in trace 00 is produced by the touchscreen PCA by a counter counting the clock pulses from the 150 shown in trace 01 and pulsing low when all LEDs have been scanned. A full scan of all LEDs is performed between each sync pulse. LED scanning starts with the columns from CR16 to CR36 then does the rows from CR2 to CR15.

Note that for every low clock pulse, there is a matching low data pulse generated by the touchscreen and sent to the 150. This low pulse originates from one of the phototransistors seeing its matching IR LED. The next clock pulse selects the next LED in the array and then checks that and so on.



The traces above show the effect of a finger in the beams. Note there are two points in the section of the data line above between sync pulses where the data line does not go low (circled in red). The first point is where the column LED (CR16-CR36) is blocked (CR28 in this example) and the next is where the row LED is blocked (CR12 in this example). The 150 firmware knows where the finger is by noting which two specific clock pulses don’t result in a matching data pulse.

Depending on the nature of a fault on the touchscreen PCA, the 150 can increase the clock speed when a fault is detected and so generate the sync pulse more quickly after which point the clock speed then reverts to normal for the next scan cycle. This is what I observed when I had the bad hex inverter that was not enabling a bank of row LEDs.