TEKTRONIX 2465B OSCILLOSCOPE: MAIN BOARD INTER-TRACK LEAKAGE.

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This article describes a complex fault which developed in one of my three Tektronix 2465B oscilloscopes. I decided to publish the details of this because it is possible that other 2465B's will develop similar problems. Although the specific details of any fault produced would depend on where the leakage conduction pathways developed on the main pcb.

There are a handful of uncoated or bare tin or solder coated pcb tracks on a small area of the main pcb (located on the board's underside, least accessible side).These tracks run close to a number of IC pins. The likely mechanism is that fine tin whiskers extend out from these tracks to the nearby pins. Curiously it is just a small area on the main pcb where these bare tracks exist just in the region of three DIL IC's. They are not a general feature of the main pcb design. The main pcb is a multilayer type with fairly broad tracks elsewhere which are well covered in a protective coating.

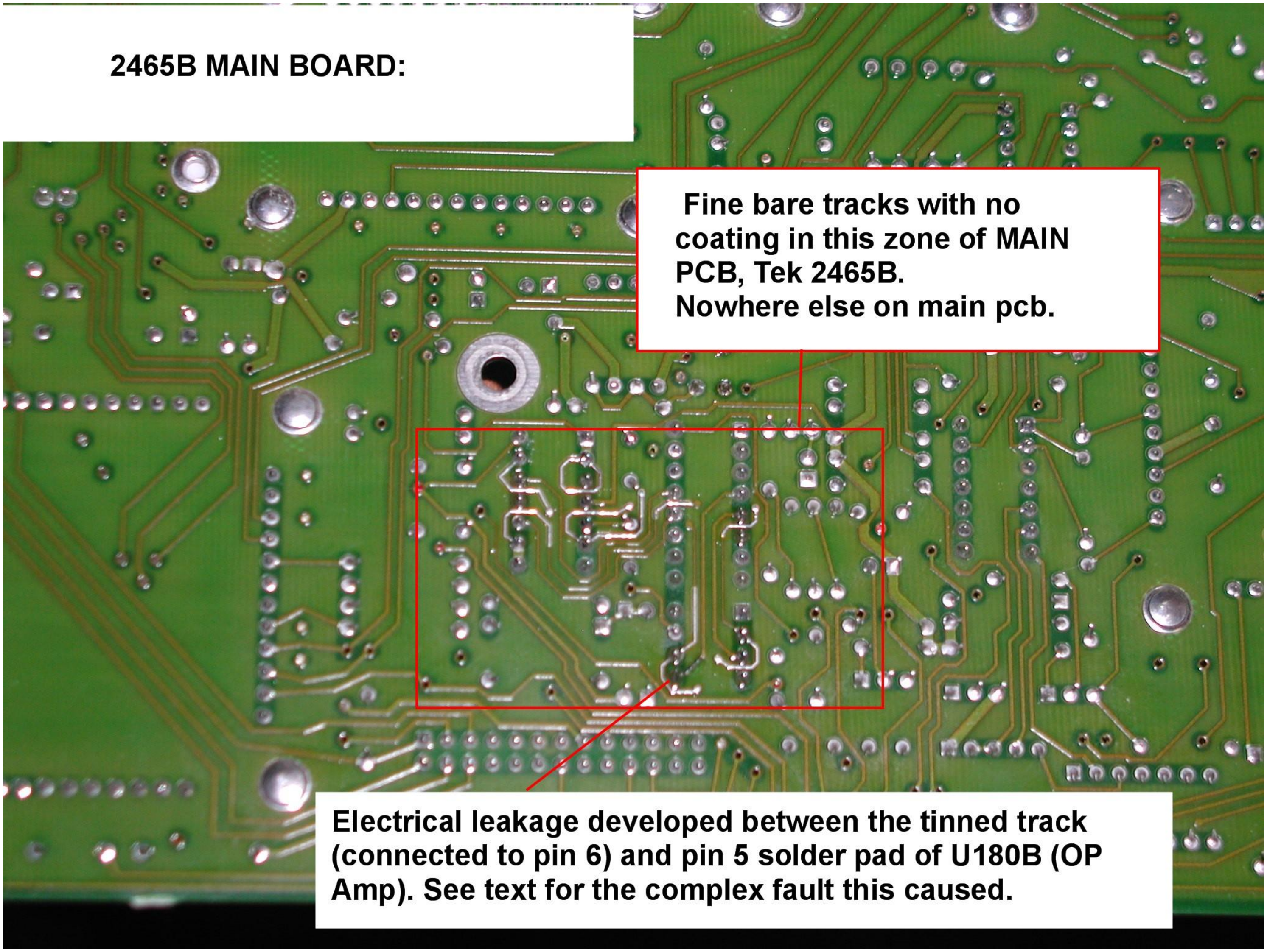
It is uncertain why the tracks in this region of the pcb were deliberately left bare or if they are coated with pure tin or a mixture of tin and lead.

The fault:

Intermittent behaviour developed first with channel 2 (CH2). The beam would occasionally deflect downward vertically and produce an erratic inverted slow sawtooth pattern, even with no signal applied to CH2. Eventually there was a constant vertical beam offset on CH2 and inputs to CH2 affected the other channels:

The CH2 vertical position control itself, or any signal applied to CH2, affected the position of the channel 1, 3 & 4 traces and the applied signal also appeared on those traces. Any applied signal also modulated the screen data display vertically too. The CH2 gain was also higher than normal and the calibration corrupted.

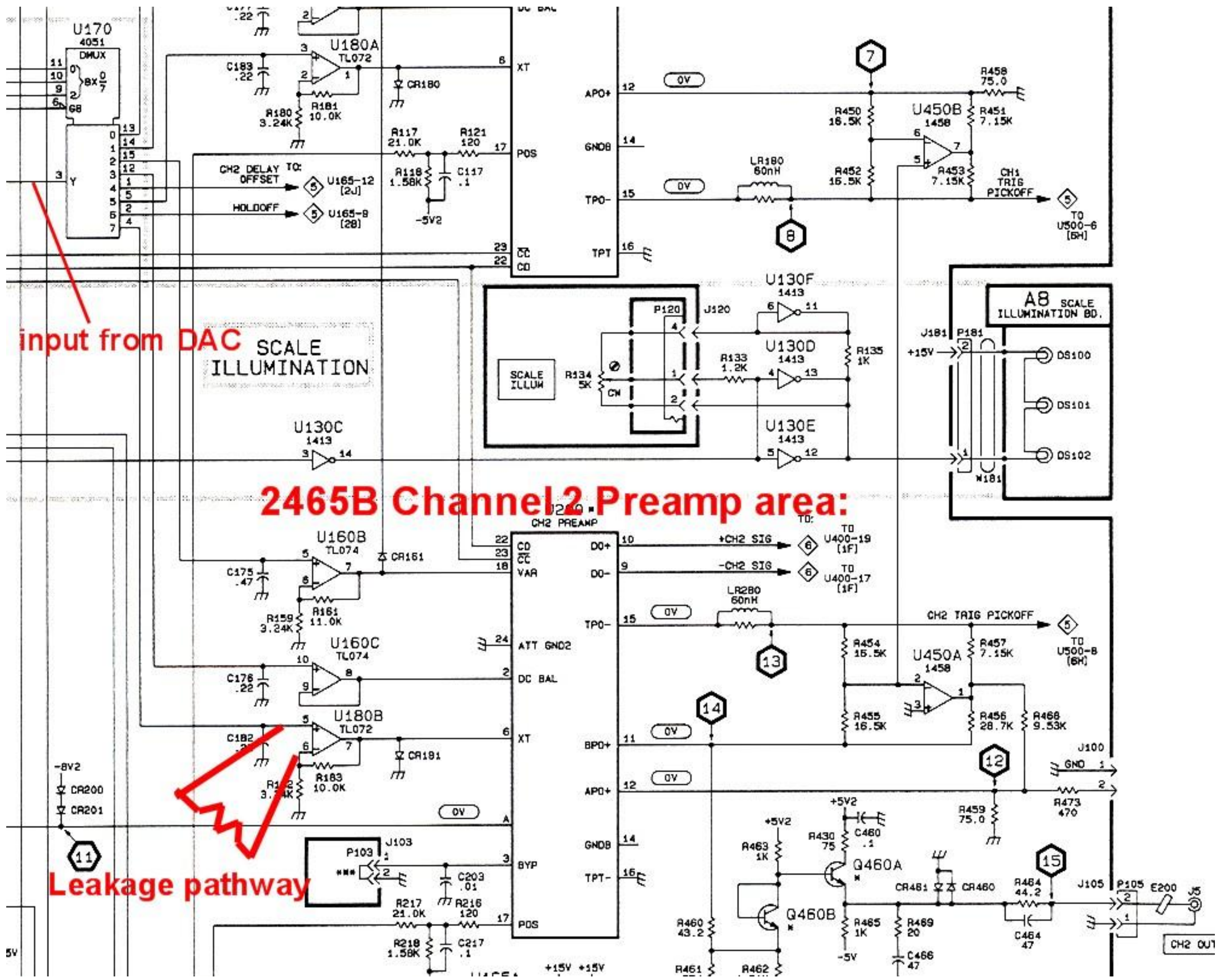
The photo below shows the location where the conducting pathway was found:



A leakage conduction pathway between pins 5 & 6 of U180B developed with time.

Testing with a digital meter showed a variable resistance of around 2Meg Ohms. It was not a direct short. Pin 5 is the + input to an OP amp (U180B) which acts as a sample hold in conjunction with U170 which is a de-multiplexer. U170 is controlled by 4 data bits and selects a specific DC output present from the DAC, this level is held until the next update by the charge in the 0.22uF (C182) capacitor on pin 5 of U180B.The circuit impedance here is very high. Only a small amount of leakage is required to discharge the 0.22uF capacitor between updates. This resulted in both an average DC offset and sometimes an inverted and erratic sawtooth like wave appearing on the CH2 trace.

The circuit is shown below with the leakage resistance drawn in.



The effect of the leakage alters the DC input to the XT input of U200, the CH2 preamp IC. This resulted in a DC offset from U200's output. Surprisingly, further down the line this upset the operating conditions of U400 (the Channel Switch IC). This caused interactions of CH 2 with the other 3 channels and with the On Screen Data display.

This effect led to an initial incorrect conclusion that there must have been something wrong with either U400 or the display sequencer IC (U650) which drives & controls U400.

The fault was found by concentrating on the abnormality of the CH2 preamp IC, in that it had a DC offset at its outputs. Ultimately the leakage between pin 5 & 6 was isolated by removing U180 from the pcb by cutting its pins near to the IC body and mounting another on the cut pins and isolating pin 5 of U180 and using a separate 0.22uF capacitor and isolating pin 4 of U170 and creating a wire link. This restored the scope to normal, and the leakage between the tracks previously connected to U180 pin 5 & 6 was easily measured with the meter.

At first I suspected that there was leakage within the multilayer pcb. However it was not until the main board was removed from the scope for inspection that I found a small very fine bridge that appeared to be a tin whisker. One stroke with the tip of a scalpel cleared it immediately. Then it was too late to take a photo.

Due to the fact these fine bare circuit tracks run near other IC pins, they were all thoroughly cleaned and painted with marine grade varnish. These bare tracks run past IC pins on U180, U170, & U160. So a very large number of interesting and difficult faults could occur if electrically conductive pathways developed between any of these tracks and the IC pins.

Discussion:

Tin whiskers are not usually a problem in apparatus such as the 2465B because the drive to eliminate lead from solder is a more recent development. However a quick internet search shows many images of tin whiskers causing trouble. They can be located inside the bodies of the AF114-118 series transistors (from the 1960's era) or whiskers can be seen bridging fine pitch IC pins or between surface mount IC's or DIL components. They can extend out from tin plated tracks very large distances, as much as 10mm. NASA has produced some interesting articles on the topic. One way to battle tin whiskers in the industry is to use good conformal coatings and add a small amount of lead to the tin.

Generally in fault finding and fault repair, the technician is led to the faulty component because the symptoms can be explained by a failure or an anomaly in a component and if the circuit design is understood by the technician it can be imagined which component would likely be responsible for a type of fault. However the faults caused by the leakage pathways created by tin whiskers are much more difficult. You could be working on a faulty piece of apparatus where there are no actual component failures. The fault is generated by what amounts to a “new circuit configuration” created by currents via the tin whiskers. Therefore the faults could seem unusual, inexplicable or “impossible” and could never be predicted by fault finding flow charts (However every technician worth their salt knows that such charts are usually worthless anyway).

In the 2465B fault described above locating the fault was made more difficult because the manifest fault was interaction of the scopes 4 channels and on screen data display and logic dictated that could only likely happen in the area of U400 where the channel signals come together. However complex IC’s and circuitry can be such that only a small change in the DC operating conditions can have unexpected effects downstream, especially in a device like an oscilloscope where the signals are generally DC coupled all the way from the input circuitry to the CRT.

On a final note I have noticed on some internet forums questions pop up about the ideal replacements for the AF114-118 range of transistors affected by tin whiskers. Also the OC169 and OC170 were very similar parts affected by tin whiskers. These transistors were used in vintage Eddystone communications radios of the mid 1960’s, also used in many other AM radios from the UK and Europe and many types of car radios from that era. The Philips AF124 to AF127 range work as replacements as they were resin potted and do not suffer from the problems, however they are a smaller physical sized part. The ideal replacement is the AF178 or AF179 which although intended for video IF work have almost identical and slightly superior specs. Also they are a physical size that more closely matches the transistors being replaced. There is only one very satisfactory replacement for the AF118 (A higher voltage video output transistor) and this is the Hitachi 2SA358.

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