The Tektronix Oscilloscope model 2465B – The U800 Problem.

Lowering the magnitude of the thermal cycling experienced by U800.

(Dr. H. Holden. Sept 2022)

It is widely known that the 2465B scope has a few weak points. One of these being the BBNVRAM (the Dallas DS1225).

It has been over a decade now since I published the solution to that problem using FM16w08 FRAM as a substitute. Since doing this many others have followed this example and now moved to FRAM to support their 2465B's.

Other weak points include leaking surface mount capacitors on the A5 board.

One other weak point is the Horizontal deflection output IC U800. This article is about U800.

U800 is known to be failure prone. One theory behind U800's failures have been thought to be thermal overload or thermal stress, but it is a little more involved.

The most likely reason for failure, since U800 was never known to run at outrageous temperatures is "Thermal Cycling" in conjunction with the IC manufacturing defects.

The constant heating and cooling with scope power cycling over years stresses the IC package. Due to a weakness in the internal bonding of the output transistor dies, eventually they fracture and disconnect. Typically this results in one of the IC's outputs, driving an H deflection plate, going to a high voltage and the CRT beam is deflected off screen.

More often than not to the left, but sometimes to the right depending on which lower leg output transistor loses its connection. They would not likely do this of course if the IC spent its whole life at room temperature. Over time, a decade or two, there can be a progressive drift left of the data display some 5 to 8mm before sudden total failure.

While thermal cycling cannot be avoided with use of the scope, the magnitude of each thermal cycle can be reduced by better heat-sinking of U800. This may not prevent long term failure but it could be expected to delay it. Just as failure will be delayed in scopes that have seen very few operating hours, or a U800 IC stored as a spare part in a workshop drawer.

U800 is constructed on a metal substrate greater than the length of the IC. It has a mounting tab projecting at one end. This tab has the same geometry as a TO-220 cased part.

Although, little power is required to deflect the CRT beam horizontally, in that the defection plates draw little current, the output stage must present a very low impedance to be relatively immune from capacitive loading. Also the output stage, if essentially a Class B design, must be biased into to class AB to be free from cross over distortion. This requires some standing bias current. And the output stage must run from a relatively high voltage supply (87v).

Therefore the power dissipation can be more than one might expect, given the product of voltage and bias current.

In addition, since it is a differential output stage, there will be two near identical stages with a minium of 4 power devices bonded to the metal substrate in the output stage.

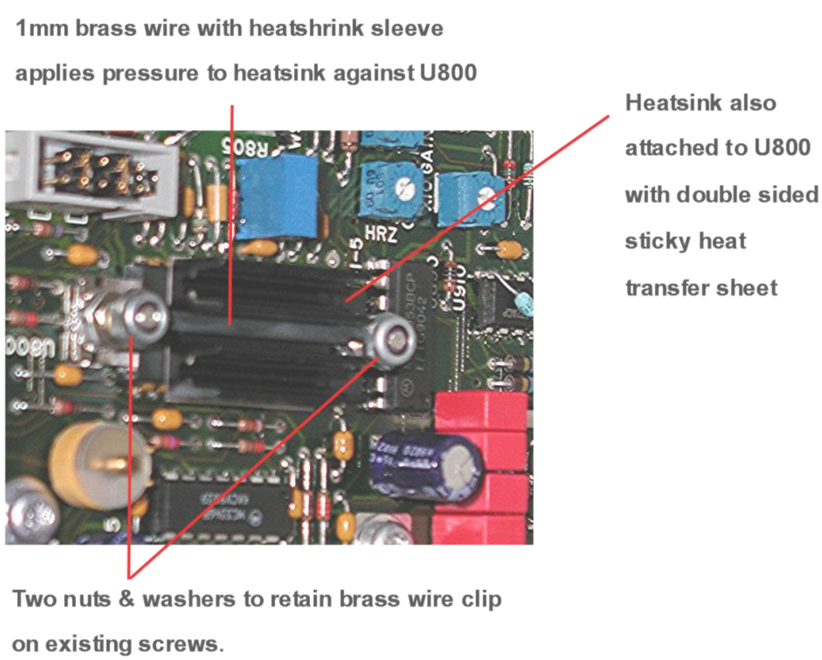
Tek chose to mount the IC in an interesting way. They placed two star lock washers around the 4-40 UNC mounting studs. This placed the metal base of U800 about 0.7mm clear of the pcb, so this limits conduction of heat into the pcb. But also, they did not apply a heat-sink to U800's metal tab.

One theory is that U800 might get better cooling with the scope inside its case, due to convection currents from the fan and heat up more with the scope out of its cabinet.

On testing it (scope out of cabinet) takes U800 about 15 to 20 minutes to reach thermal equilibrium. With no additional heat sinking U800 tab temperature increases to 32 Deg C above ambient. So if it is a typical 20 Deg C day the tab temperature rises to 52 Deg C. This is not an outrageous value, however if the abient temperature was 40 Deg C then a tab temperature of 72 Deg C is not wonderful for the IC in the long run.

Various internet photos have shown heat sinks, as an afterthought, attached to the top surface of U800 to improve the situation.

I had previously attached a 4 finned 22 x 16.5 x 10 mm aluminium heat-sink to U800 with thermal pad and held down with force via a wire clip.



It does have some use. Testing shows that it lowers the tab temperature of U800 by about 4 degrees C. The reason it is not more effective is because of the thermal resistance of U800's epoxy package. Really, an added heat-sink should be applied to U800's metal tab to be very effective.

Despite having a heat-sink added, one of my scope's developed a U800 failure recently. So I thought I would re-visit the idea of how to better heat-sink U800.

There are two scenarios:

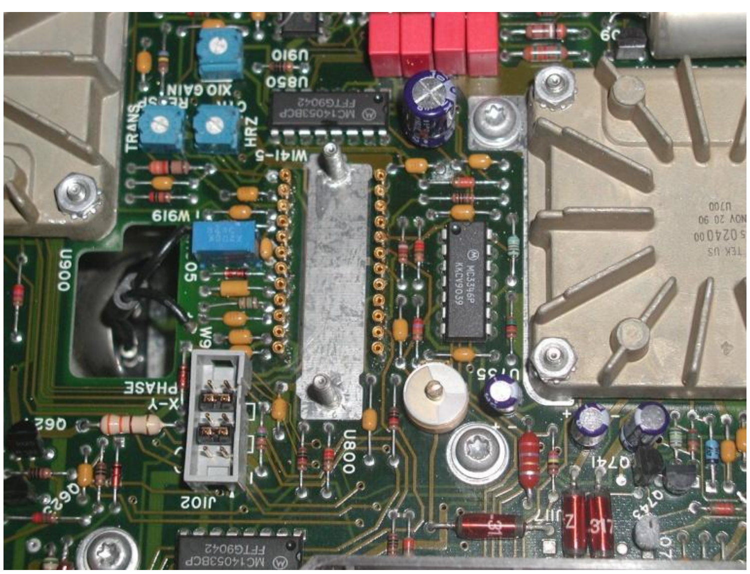
1) U800 has failed and requires replacement and needs to be removed from the pcb.

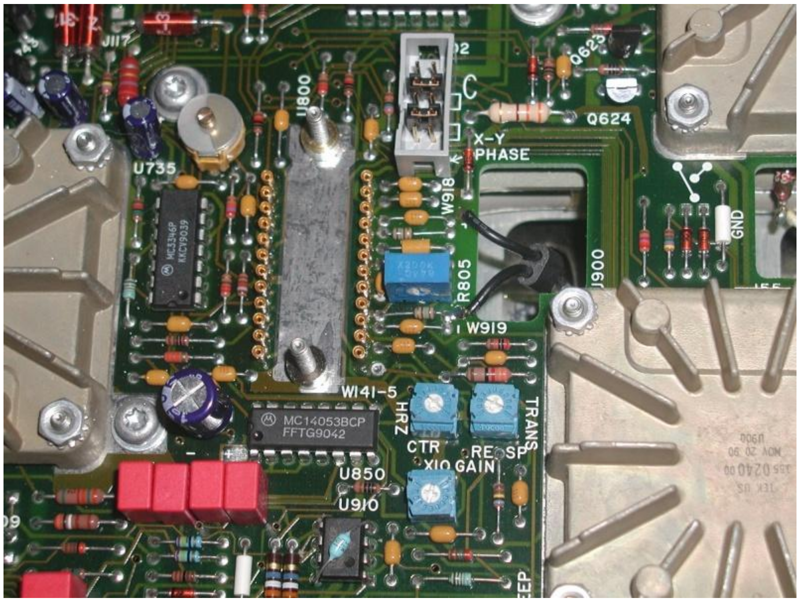
2) U800 is still ok, and needs to be better protected.

1) In the first case I found I could easily remove the defective U800 from the top board surface without having to remove the main board. This was done by cutting U800's pins close to the IC body with small needle nosed cutters. The pins were removed one by one after fresh solder was applied. A small paper tray was crafted to slide under the U800 area to catch any debris that might fall through adjacent holes while sucking the holes free of solder.

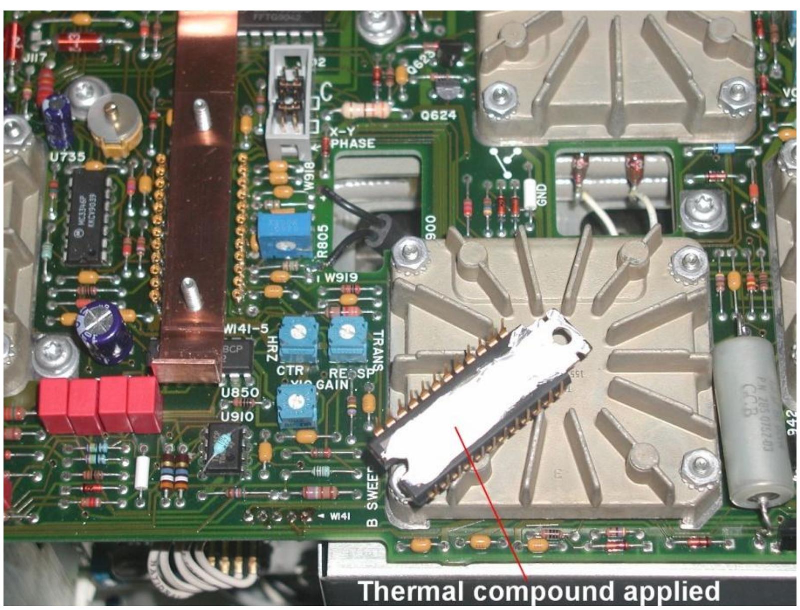
Since U800 was already lifted off the board 0.7mm, I decided to increase that by fitting an array of gold plated socket pins (taken from an Augat IC socket). The pin array was supported in its alignment from a side section of another IC socket and the pins were placed on their holes and aligned to be about 0.3mm above the pcb surface. This small gap allowed the solder to enter the mouth of the plated through holes, filling the hole around the IC pin. The upper part of these pins then sits about 5mm above the pcb surface and when U800 is plugged in, the bottom surface of U800 now sits 4.5mm above the pcb surface.

Two 6mm OD, 3mm ID and 3.5 mm brass spaces were prepared:

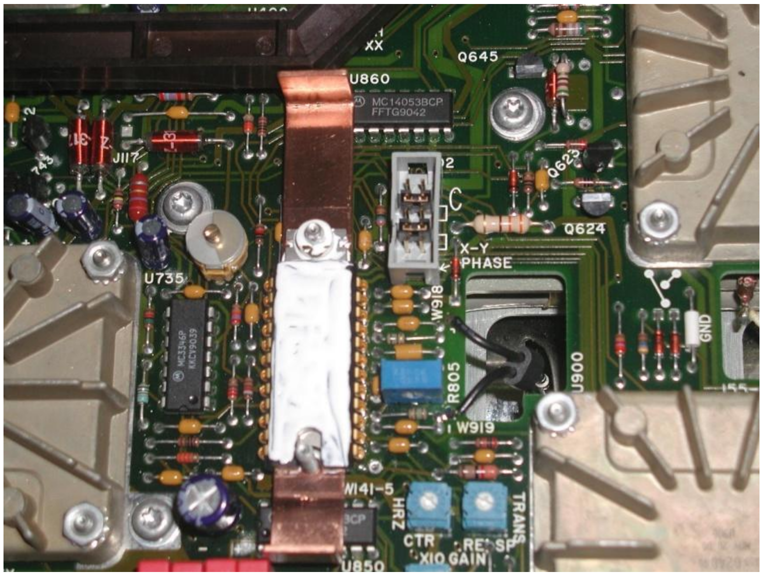




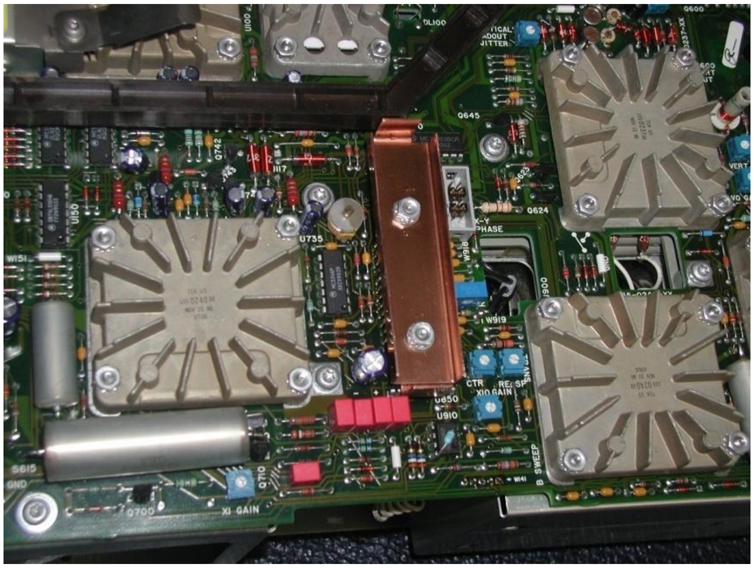
1mm thick copper heat fin was fabricated (see dimensions below) then thermal compound was applied to the metal base of a new U800 and U800 was then plugged in. In this version of the repair, not only did it not require removal of the main board, but U800 can be easily removed at a later date without soldering.



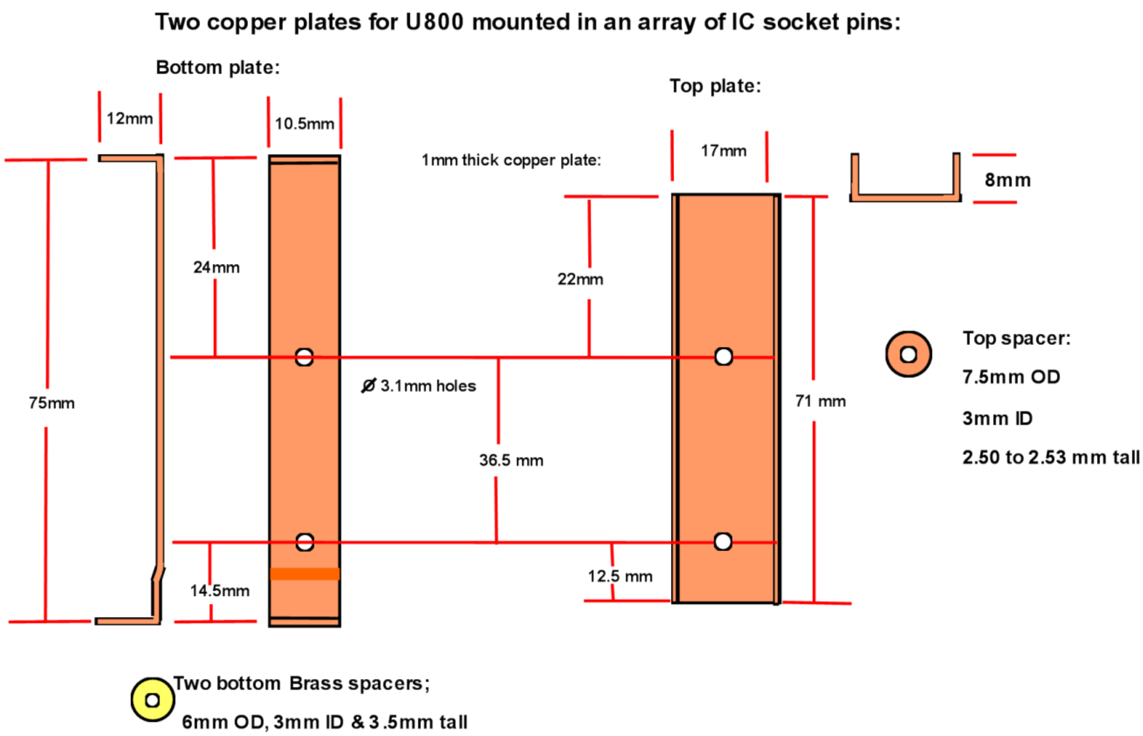
The IC is then laid over this initial heat flag and a 2.5mm tall (custom machined) copper washer is added on the stud over the tab and coated with heat transfer compound. The washer raises the level above the metal tab to be equal to the top surface of the IC. This first heat fin on its own, despite being coupled to the IC's entire metal tab, is not large enough in surface area to adequately cool the IC.



More thermal compound is applied, this time to the top of the IC (picture above) and the 2.5mm tall copper spacer washer on the tab. The upper cooling fit is then fitted and locked down with two flat washers and the usual Tek nut/star washers.



The method results in a large surface area with good thermal coupling to both the metal tab and the IC's epoxy case. The top plate fin upper edges sit close to 16.5mm above the pcb surface. This gives a satisfactory clearance with respect to the scope's metal case.



Thermal result:

With the above method, the temperature rise of U800's tab is around 18 to 20 Deg C above ambient (scope out of cabinet, compared to 32 Deg C without the copper heat fins).

Also, it is possible, that with U800 clamped between these two fins, it may also provide some mechanical resistance to expansion of the epoxy package with heating. This may also help to prevent internal delamination effects over time.

2) The case where U800 is working and requires better thermal protection:

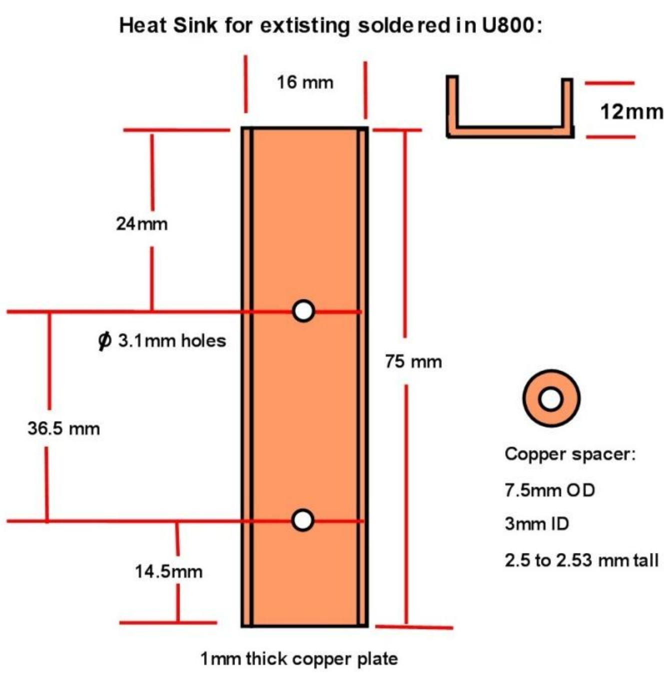
In this case the hardware is simpler. One copper heat fin only is applied.

Due to the fact the IC's top surface level above the pcb is 4.7mm, then this heat fin's side flanges can be taller (about 12mm) for the same cabinet clearance. It requires the same 2.5mm tall custom copper washer to transfer heat from U800's tab. It also requires the thermal compound applied to the top of U800 before it is bolted down.

The result is very similar to the twin fin method with U800 case temperature rising only 18 to 20 Deg C above ambient temperature, versus the 32 Deg C it does with no heat sinking.

Overall this heat fin has a very similar surface area to the combination of the two heat fins used in the case that the U800 was in socket pins, both arrangements having a total surface area (one surface) of 3000 square mm or 30 square cm.

This is far preferable to the original method of attaching a small heat sink to the epoxy top of the IC and not the metal tab which only lowered U800's tab temperature by only 4 Deg C.



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