SOL-20 "POWER ON" LOCKUP PROBLEM USING THREE 16KRA PROCESSOR TECHNOLOGY (PT) RAM BOARDS.

(H. Holden, Oct.2018).

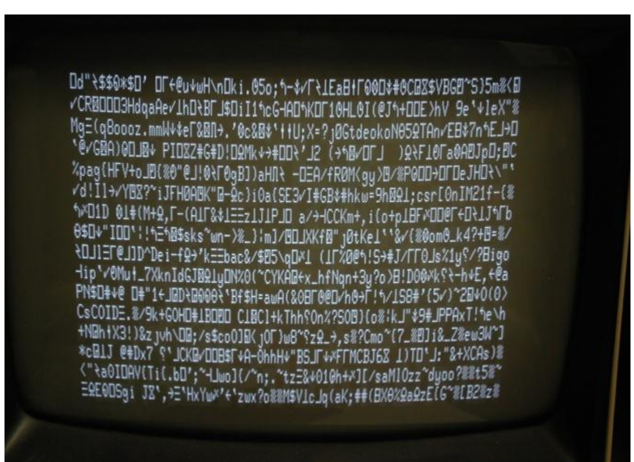
Fault description:

I had fitted three known good and tested PT 16KRA ram cards to my SOL-20 computer. Along with those a North Star Double Density disk controller card, so as to be able to run a dual floppy drive assembly (using Mike Douglas's VSG) and run 48k North Star CP/M.

All seemed to be going well, until I powered the computer up with the three 16KRA cards and the North Star card. It would not boot to Solos normally and locked up with a screen of graphic symbols. No cursor appeared and the keyboard was non responsive too. In addition the hard CPU reset provided by pressing the upper case and repeat key, did nothing. Nor did a manual reset applied to the CPU. I found that if I unplugged the North Star card all seemed well on power up, making me initially suspect the North Star card (how wrong was I there). The picture below shows the locked up state. When I changed the video ram IC's on the main board for a batch of other IC's, it just showed different symbols.

After many power on attempts I discovered that very occasionally, about 1 in to 20 power-up attempts, just with the three PT 16k cards present, the lockup state would still occur without the North Star card present. That took the suspicion off the North Star card. The fault also never presented with any two, or any one, of the 16KRA ram cards on the bus. There had to be three PT 16KRA cards present on the bus to get the condition. The photo below shows a typical "locked up state" at power up.

One other observation was that using two PT 16KRA ram cards, and one Seattle computer 16K standard card, the problem never materialized. I would find out the reason for this later.



Finding the problem:

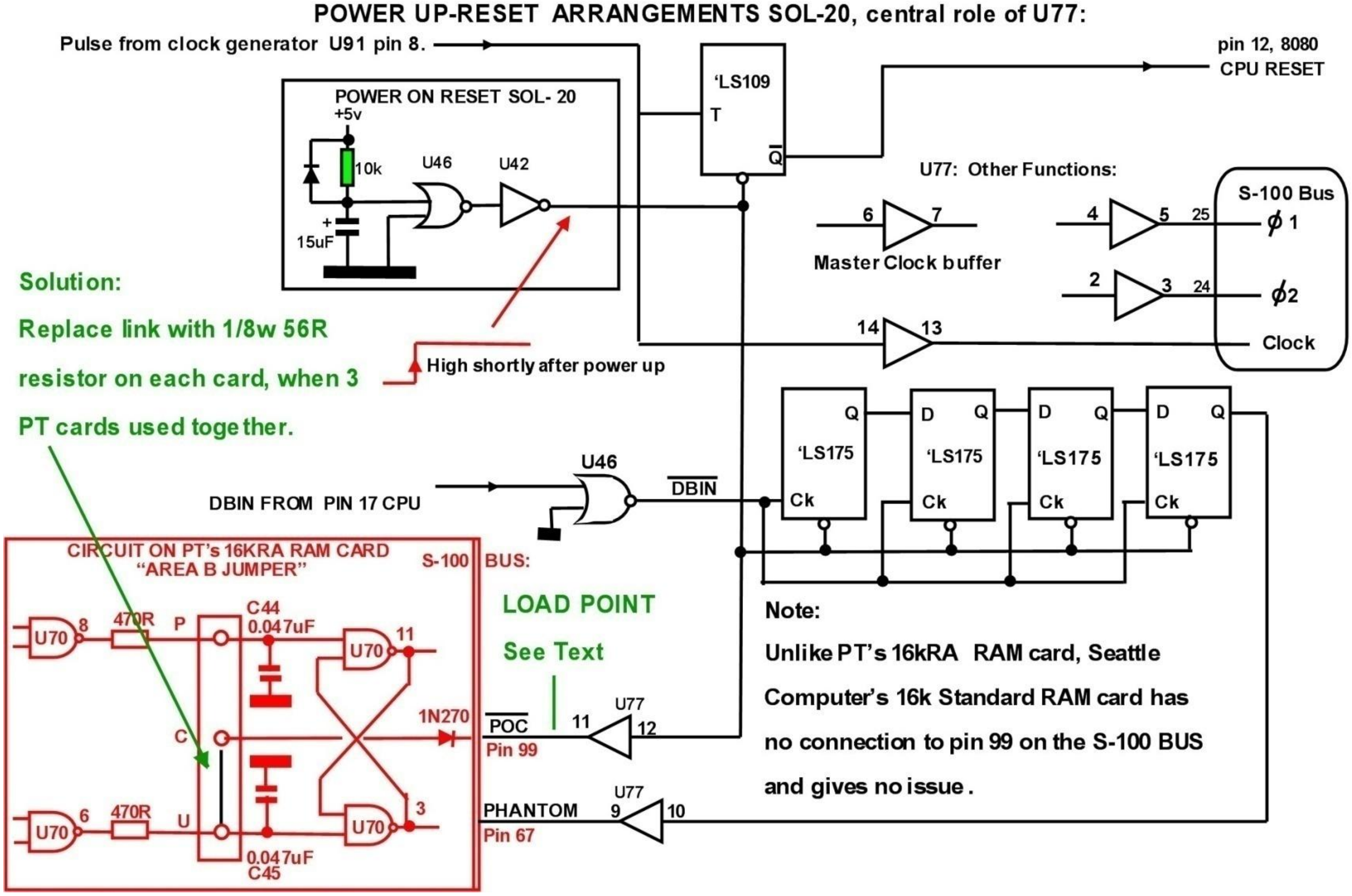
This was very difficult and I had to burn the midnight oil on a few nights. After seemingly being beaten, I used a 1000pF capacitor, one end earthed and connected the other end to each of the S-100 bus pins, prior to a power up, with just two ram cards present. When I applied it to pin 99 of the bus, this generated the lockup effect, even in the case of no cards at all on the S-100 bus.

Experiments then showed that any capacitance added here of greater than about 350pF to 400pF generated the malfunction or lock up. Also I tried a large capacitance of 0.1uF with a series resistor applied to pin 99. Experiment showed that if the series resistance was below about 35 to 40 Ohms, the same fault materialized, even with no cards on the bus.

Pin 99 of the bus is driven by the 8T97 buffer IC U77. I changed it to a 74LS367 (equivalent as I did not have an 8T97 in my parts), and there was an improvement, but after trying a range of these IC's I came to the conclusion that the original IC was not in fact faulty, it is just that some IC specimens could tolerate a higher capacitive loading on their output on pin 11 before the malfunction appeared.

So I investigated the IC, U77 that drives pin 99 of the bus and the circuitry on the bus. U77 plays multiple roles in the clock and power reset circuitry, see simplified diagram below:

POWER UP-RESET ARRANGEMENTS SOL-20, central role of U77:



Looking at "Area B" of the PT 16KRA ram cards, this area jumper is to set if the memory is operating in *protected* or *unprotected* mode and how it might behave when power is initially applied or restored after a power failure. I'm not sure of the application of this as Ram is "Forgettory" and after a power failure has lost its data, unless they are referring to what might happen after a short (transient) power glitch or very brief power supply dropout.

The circuit on PT's 16KRA ram cards in "area B" has substantial capacitance. With, three cards in operation together, then three 0.047uF capacitors (one per card involved at a time depending on the jumper) are present, bringing the total capacity, albeit coupled by diodes, to about 0.14uF.

In addition, at power turn on, pin 8 and pin 6 of the Nand gates U70 are high (although pin 6 has a negative going 1uS long pulse on it, but this integrated to a logic high level by the series 470R and 0.047uF capacitor to ground). This means that the 1N270 diodes, initially at least, are in forward conduction coupling (or switching) this capacitance to pin 11 of U77, because at power up, pin 11 of U77 is low until the power on reset circuit times out. But this diode coupling is not exactly the same as coupling the total capacitance directly to pin 99 of the bus. This is because when the bus line pin 99 or output of U77 pin 11 goes high, the diodes are not conducting.

(In addition to the above experiments, I also attempted adding additional bypass capacitance to the power supply pins of U77, this did not help. Also I altered the area B jumpers with no effect)

So given that I had already demonstrated that any capacitance greater than about 350pF to 400pF loading pin 11 of U77 would cause the malfunction, how could it have ever worked, even with one card, with at least a 0.047uF capacitive load ? But I had also noted that a large value capacitor was tolerated, loading pin 11 of U77, provided there was a series resistance was greater than about 40 Ohms.

The answer why it worked at all is likely the effect of the 1N270 diode, but as noted as the voltage on pin 11 rises, the diode current falls and eventually the diode effectively uncouples the drive signal from pin 11 of U77 from the 0.047uF capacitors. So the loading on U77 is more complex than a direct connection to the capacitor. The diode has an effective forward resistance too, and the voltage drop does depend to an extent on the current.

It transpired that with one or two 16KRA cards on the bus, there was no apparent issue. However with three 16KRA cards a borderline case, with the occasional lock up on power up. But with a small additional load (the North Star controller card makes a connection to pin 99) added, enough to make the lockup or malfunction present at nearly every attempted power up.

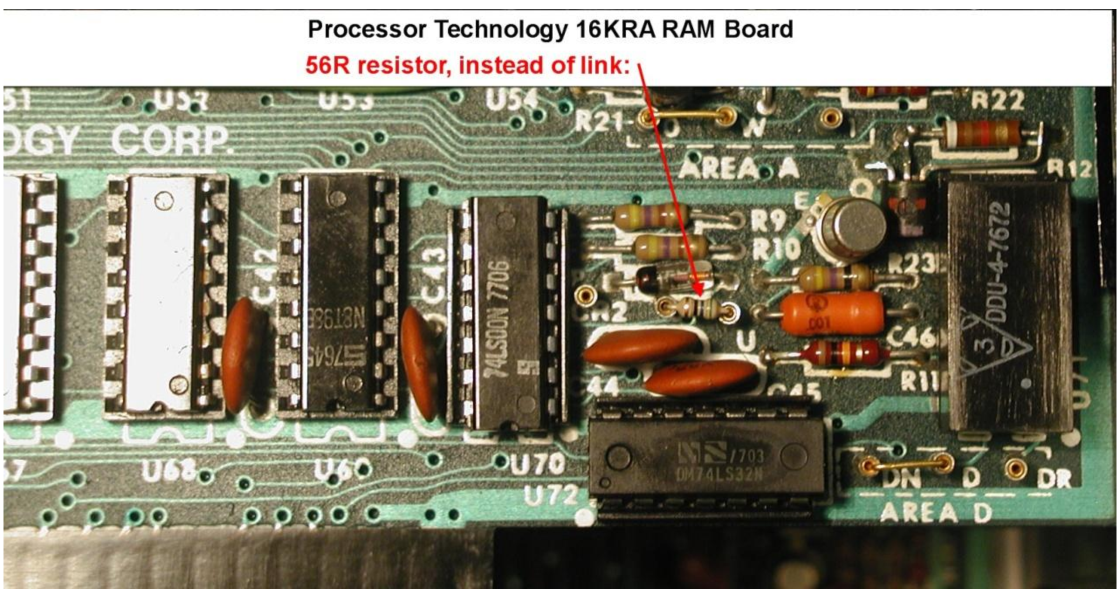
Solution:

Initially I removed the 0.047uF capacitors from the 16KRA ram cards. This solved the problems, no lock ups in 50 or more attempted power ups with the three 16KRA ram cards & the North Star card present too. So that might have been one type of fix.

However, I'm not 100% certain of the requirements for those capacitors. Clearly they are a pulse integrator and or a delay circuit. Given the outputs of that circuit drive an SR flip flop, it (the flip flop formed by the two Nand gates of U70) will likely remain in one stable state depending on the jumper selection. I decided though, it would probably be better to keep the capacitors there as PT had designed it and come up with a better solution, without modifying the 16KRA ram cards to any extent.

I decided to simply replace the wire link in Area B with a 56R 1/8W resistor (see photo below) on each of the three 16KRA ram cards. This still takes the junction of the 470R and 56 R resistor (the inputs to the S-R flip flop) below logic 0 (to about 0.95V) when pin 11 of U77 is low, but it electrically isolates enough of the load capacitance that even when **three** 16KRA ram boards are used, as well as the North Star card present too, that the worst IC 8T97 IC specimen for this problem (placed in location U77) does not malfunction and no lockup state occurs at power up.

The photo below shows the resistor in "Area B" inserted in to the pcb sockets, instead of the wire link:



I would therefore recommend that if three 16KRA processor technology ram boards are used in the same Sol-20, and especially if another card is used that connects to pin 99 of the S-100 bus, that 56R resistors are used instead of wire links in the Area B jumper option of the 16KRA ram board.

Further Discussion:

It was interesting to compare different IC specimens for U77 and the results of loading down pin 11 of the IC experimentally, with various loads and checking the effect on power up:

I compared three 8T97 IC's. In each case with a capacitor from pin 11 to ground, the fault is generated (with no cards on the bus) with a capacitance around 400pF. This is quite different to the 74LS367AN which can tolerate about 3000pF before the fault is generated. This is interesting, because the 8T97 IC on its data sheet is characterised for a 500pF load which simply delays the gate propagation time from around 20nS to 50nS.

Using a large test capacitance of 0.1uF and series current limiting resistor (which is effectively what the IC is up against in the SOL-20 application, driving the 16KRA boards due to the germanium diode's resistance and the 0.047uF capacitors) a resistance of less than about 40 ohms is enough to generate the fault for both the 74LS367AN, or the 8T97. This was one other reason why I elected for the option of using the series resistance (in series with the 1N270 diode) instead of a zero ohm jumper on the pcb, rather than attempting to change the capacitive loading on the 16KRA ram cards.

Another option: One possibility to remedy this fault condition might be an alternative IC for U77. Using a good 74LS357 specimen the fault was virtually absent perhaps only one in 30 power ups, compared to the original 8T97 IC. So some IC's are better at dealing with heavier loads on their outputs. I considered an option might be the 74F367. I have ordered some to try. At least with the 56R added resistors, it will work with three 16KRA ram boards, regardless of the buffer IC specimen.

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