Dave Langley's
Williams Video Game PCB Repair Log

This document is a log of all the symptoms and remedies for various faults I have fixed on Williams video game PCB's for the games Defender, Stargate, Robotron, Joust and Sinistar. Where possible I have tried to explain the theory behind *why* the symptoms were seen for a particular fault, but this is not always possible (my understanding of the Williams hardware architecture is not complete, but I learn more with each fix!)

Disclaimer: While I have endeavoured to make all the information within this document as accurate as possible I cannot be held responsible for any errors or omissions, or if your soldering/diagnostic skills are not up to the job. Be warned; if you fry your boards, your game, or yourself I will not be held responsible!

If you spot any errors or omissions please Email me from my Website at
http://www.robotron-2084.co.uk/

My Website also contains technical information and links relating the Defender, Robotron, Joust, Stargate and Sinistar, including manuals and schematics. Feel free to visit sometime …

Due to the limitations of word '97 I cannot write signals such as 'read NOT write' as it is not possible to have the NOT bar above the text. For the purposes of this document I shall use underlining as a means of identifying a NOT signal, for example 'read NOT write' will be written as R/W.

Before starting any testing on boards I strongly recommend that you check your power supplies ensuring that the earth (or ground) +5, +12v, -5v and –12v power supplies are good. You will be wasting you time trying to fix a non-working board if the power supplies are bad.

I have split this document into 5 sections, one for each type of board. They are as follows:

Section 1: ROM Boards

ROM Board 1: Defender Later Series ROM Board with red-labelled ROMs

Symptoms: Dead!

On first power up this board was totally dead. Upon inspection it had some repairs to a few tracks on the PCB and some of the jumpers had been moved, but the repairs were good and it was correctly jumpered for red-labelled ROMs. When wiggling the ribbon cable it or just by touching the whole board it would occasionally burst into a rug! Suspecting a loose connection I removed the covers from the ribbon cables and gently squeezed the IDC contacts onto the wires to ensure a good connection.

When I power the board up again, the fault was still the same … oh well it's never that easy.

Next I verified the ROMs. While removing them two of them they were so brittle that some of the legs were left in the chips sockets. While verifying them one also came up with a bad checksum. All three were replaced.

Now when I power up I get a rug and game over mode … that's better! However there is no sound and the 4 LEDs do not seem to be working properly, they are just lighting up randomly. After 1 or 2 minutes (or sometimes less) the game resets.

Straight away I suspect the 6821 PIA chip (the big 40 pin one). In all the faults I have fixed on various boards this is the second most common failure (after the 4116 RAM). The 6821 PIA chip was duly replaced.

Now on powering up I get sound and an 'All systems go' message, but LEDs 1 and 2 are still not right and when the 'All systems go' message disappears the game does nothing but a blank screen.

Still looks like the PIA, but this was a brand new one so I don't think it's that. I swap it with a known good one (I always socket chips when replacing them) just to be sure and the PIA is OK.

Now I start probing around the signals on the PIA chip … pin 21 (R/$\underline{W}$) is floating. Additionally, when my logic probe is on pin 21 the game runs at about ½ speed! Weird huh? Now with power off I check the lines to pin 21 of the PIA. Not connected to the R/$\underline{W}$ signal. I run a jumper from the nearest point that has the R/$\underline{W}$ signal on the board and hey presto there board is working!

Theory: With the R/$\underline{W}$ signal not applied to the PIA the game is stuck in read and cannot write to the RAM? Why touching pin 21 with my logic probe makes the game run is anyone's guess, though I suspect it must be dragging it just high/low enough for some processing to happen!

ROM Board 2: Robotron with orange and red-stripe labelled ROMs

Symptoms: Game works and plays fine but all the text is corrupt.

At first I suspected a bad ROM, however I swapped the ROMs with my blue label set and still the fault persisted. My second theory was that one of the Special Chips 1's was bad. Again I swapped in good ones but still no change.

A this point I scrutinised the board and spotted a damaged strand in the ribbon cable. The line furthest away from the earth looked like it was chaffed. When I tested it with an ohmmeter it turned out to be open circuit!.

The cable was repaired and the board works fine, in fact this is the board installed in my Robotron and it gets played nearly every day!

Theory: I never looked to see what signal is sent along this line to/from the CPU so I have know idea … a damaged cable will need repairing whatever signal is on it, so that's exactly what I did.

Notes:

1. I have a bad SC1 and it gives me RAM errors on a known good CPU board, if I change the SC1 for a working one and all is well.

2. Most ROM errors will be reported by the ROM board's diagnostics program, however, the diagnostics will reside on one of the ROM chips and if that is bad the Board will be dead. I have seen this on Sinistar (ROM 11). I have no idea which ROM it is on the other games.

Section 2: CPU Boards

CPU Board 1: Early series Defender with weird looking static rug.

Symptoms: When booting the game the rug is not the normal pattern and it does not sweep across the screen. It is changing though so there is some CPU activity going on.

Whilst probing around the memory with a logic probe I discovered the that on pin 3 of all the RAM chips WE was no strobing. I checked this on a working Williams board and it should be strobing. I traced the WE 1, WE 2 and WE 3 signals (one for each RAM bank) back to the 7410 (a triple 3 input NAND gate) at location 6F which did not give an output even though its inputs were OK. The 7410's main input is the WE signal and it feeds the 7402's (locations 3G and 4G), 7432 (location 3G) and 7427's (locations 4F and 3H) that produce the WE 1, WE 2 and WE 3 signals.

The 7410 was replaced and now the board is now stuck in the rug. As the RAM on this board is still untested I replace it all with a known good set on a whim.

The game now boots correctly and comes up in bookkeeping mode. In the bookkeeping mode all the parameters that are recorded come up as ?????. This is a suspect CMOS RAM failure (I'm not using any batteries, so resetting the game (not power on off) will restore factory defaults if the CMOS is OK.

The CMOS RAM was replaced and now the game works fine!

Theory:

1. With the WE signals not being fed to the RAM chips they will be suck in either read or write depending on whatever the output was stuck at from the 7410 (I can't remember), obviously this will impair system performance!
2. A bad RAM was causing the game to be stuck in the rug. Just one of many odd effects of a bad 4116 RAM! See notes below for more details.
3. A bad CMOS RAM chip will not allow the game to boot. If the settings cannot be retrieved the game will be stuck in bookkeeping.

Notes:

1. Memory errors cause a lot of problems with these Williams CPU boards. The 4116 RAM that was supplied with the boards requires +5v, +12v and –5v DC. The original Williams linear PSU's are now at an age when they will start to fail in large numbers, if the 4116 RAM loses one of it's power supplies but the others continue then the RAM can be damaged. Even worse, the original Defender PSU had no over-voltage protection and in an over-voltage situation then major damage may be done to the board(s). Fitting a modern switching PSU is not without it's problems though, the Williams linear PSU's different voltages all came on in a specific order to allow orderly power up and shut down. When using a switcher this does not happen, whilst your board will not be damaged the settings and high scores held in the CMOS RAM which is backed up by the 3x AA batteries can occasionally get scrambled. Not really a problem but certainly an annoyance! If anyone has a solution to this please Email me!

CPU Board 2 Notes continued …

2. I have seen some failed RAM chips cause problems that you would not expect to be RAM. . Here are some that I can remember:

   (a) Game sticks in rug
   (b) Game reports 1-3-1 error with known good RAM in that position.
   (c) Games dead.

   Therefore if you have problems with you game and you think it *might* be the RAM, remove it all and re-insert it one chip at a time powering up between chips to see what symptoms you have. This is not so easy with Defender as the diagnostics are not that good for RAM. If you have another working CPU board, verify it by fitting the RAMs one chip at a time.

3. CPU Board 2: Early series Defender with no sync.

Symptoms: The game will not sync with the monitor, and is not working.

Whilst probing around the memory with a logic probe I discovered that on all the RAM chips memory address 6 (MA6) was stuck low (or was it high I forget), anyway this SHOUL be strobing and was not. After looking at how MA6 is generated I discovered that the 74153 (a dual 4 to 1 data inverter) at location 3Q was bad.

After the 74153 was replaced the game appeared to be in the same state, although I now had memory address line MA6 operation correctly.

I removed and tested all the RAM. Every single RAM chip on this CPU board was DEAD! They were replaced with known good ones (once I had verified that the 0v, -5v, +5v and +12v power supplies were present at the chip sockets). Still no rug and no sync.

As the game was no syncing to the 14" cub monitor on my test-bench I decided to look at the sync problem next. Using the logic probe on the V sync and H sync monitor outputs I discovered that there was no vertical sync pulse at all. From the Williams schematics the vertical sync is generated by using video address bus lines VA9 to VA13. By probing around the video address bus I found that VA8 to VA13 were all stuck high (or low?). This is where it all gets a bit complicated!!!!

Lets talk about how the video address bus is generated …

> The video address bus is a 14 bit wide (VA0 to VA13) bus that counts from sequentially though all the possible binary combinations of 14 bits to address each pixel on screen in turn. This is achieved by linking four 9316 4-bit binary counters (at locations 2L, 2N, 2O, 2Q) together in a chain 16 bits wide. You can also use 74161's (which is good 'cos they cost about one tenth the price).
>
> A 4MHz clock is applied at the to the first stage, but the least significant 2 bits are not connected to the video address bus, so bit 3 becomes VA0. This means that the video address bus counts at 1MHz. This part is quite simple, the video address counts from 0_{10} to $16{,}383_{10}$ at a rate of 1MHz, however, the elapsed time from a count of 0_{10} to $16{,}383_{10}$ is 16.4mSeconds. The video address bus needs start counting each 16.6mSeconds so when the count is at $16{,}383_{10}$ the first time a 7474 (dual D type flip-flop) at location 5H is toggled, this has the effect of resetting the count to $16{,}128_{10}$ and the count resumes until again it reaches $16{,}383_{10}$ the 7474 t location 5H is again toggled this time the video address bus is reset and the whole process starts again.
>
> This may sound complicated and indeed it is, in fact I never would have worked it out without the Defender theory manual (Williams cat no 16P-3001-300 October 1991). If you have trouble in this area I recommend that you download this and read the in depth description of the theory behind the video address bus generation. There is a scan of this hard to find manual available for download from ftp://www.stormaster.com/pub/RGVAC-Manuals/PDF-Arcade/.

Well back to the repair in hand … on this particular video address bus, the 7474 at location 5H was bad and the D and Q lines (linked to each other) were floating. The 7474 was replaced and hey presto! We have a rug!

We are not out of the woods yet though as the game is now coming on stuck in bookkeeping mode. From my previous repair (just a few days before) I'm petty sure that this is a bad 5101 CMOS RAM chip at location 1I. In the bookkeeping mode all the parameters that are recorded come up as ?????.

The CMOS RAM was replaced and now the game boots OK, but as soon as it comes up in game over more it resets and the so on. Occasionally it will last as long as 10 seconds in game over mode, but never long enough to start a game!

The board is still in this state as I have not had time to look at it any further sine I got my Robotron Cabinet … that's another story, but it needs a LOT of work!!!!!

CPU Board 3: Sinistar –blank screen

Symptoms: Rug displayed, then the 'All systems go' message then a blank screen.

This was an easy one. The day before I got this board in I was reading a document called the Ranger chronicles (a series of Williams tech articles by mike ranger) and he had a joust which displayed similar symptoms. Anyway I tried his fix of replacing the 6809EP CPU chip at location 1E and the game roared into life.

Thanks mike. Your series of documented fixes are the inspiration for this document!

Theory: The CPU was not giving out ready/write (the R/$\overline{W}$ signal) access to the RAM and therefor nothing could write to the video RAM. This is very similar to a Defender ROM board problem I had, in that I is the same signal but a different cause!

Section 3: Widget (Interface) Boards

Widget (Interface) Board 1: Sinistar

Symptoms: No reaction to switch inputs or occasionally intermittent reaction to them.

With the board connected to my test bench and powered up in switch test mode I started probing around. When the ribbon cable is wiggled, the inputs start flashing on and off:

Clearly this is a bad connection on the ribbon cable, this is quite a common fault. I have seen it at least three times on interface boards and once on a ROM board. Most of the boards I get have been in storage for up to ten years and some have not been stared very well. It is quite normal to find boards with impact and/or storage damage.

Its easy to check for bad connections with an ohm-meter, but be sure that you are moving the cable around while you are doing it otherwise you may not spot an intermittent connection.

It is also an easy fix. If the ribbon is not damaged then gently pry open the covers at both end of the cable and gently squeeze the IDC contacts onto the wires to ensure a good connection. Replace the covers and try it!

If the cable is damaged it will have to be repaired or replaced.

Theory: With some of the cable inputs/outputs missing then the game will not get all the signals it was expecting.

Notes: I have seen this fault three times, but it could be possible for other symptoms to also be the ribbon cable. I seem to remember from the distant past I fixed an interface that was holding a CPU in reset by replacing the ribbon cable …

Widget (Interface) Board 2: Robotron

Symptoms: When in switch test rapid changing of switches reported as ‘on’ and after about 1 minute the CPU reset.

After checking the ribbon cable (see Widget board fix 1 above) and ruling it out I suspect the 6821 PIA chip (the big 40 pin one). In all the faults I have fixed on various boards this is the second most common failure (after the 4116 RAM). The 6821 PIA chip was duly replaced.

When booting the game with the replacement PIA fitted all everything works fine. If only those tanks Robotrons were not so difficult!

Theory: Bad outputs from the PIA causing the CPU to reset.

Widget (Interface) Board 3: Joust

Symptoms: Dead.

Although the game looked like it was dead, it was actually held in reset. After checking the ribbon cable (see Widget board fix 1 above) and ruling it out I suspect the 6821 PIA chip (the big 40 pin one). In all the faults I have fixed on various boards this is the second most common failure (after the 4116 RAM). The 6821 PIA chip was duly replaced.

When booting the game with the replacement PIA fitted all everything works fine.

Theory: Bad outputs from the PIA causing the CPU to reset.

Notes: I have seen this fault three times, but it could be possible for other symptoms to also be the PIA.

Section 4: Sound Boards

At this time I have not repaired any Williams sound boards. I do currently have three to work on though!

Section 5: Sinistar Speech Boards

Speech Board 1/2/3: No Speech/Quiet Speech /Course Speech

Symptoms: Various speech boards with no speech, quiet speech or course sounding speech.

There is very little to these speech boards. I verified the ROMs in a working board and once I confirmed they were OK there were only two likely candidates. The 55516 CVSD speech chip (which I have never been able to source) and the two 1458 dual op-amps IC's 2 and 3. In all three cases it has been these op amps that have failed in a speech board with working ROMs.

Theory: No/bad amplification = no/bad speech!