Z-100 LifeLine
Since 1989

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#139

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The Seagate ST-251 Hard Drive Stiction Revisited

I have accumulated quite a number of these drives over the years, nearly all of which had some problem or another and they were taking up shelf space. Unfortunately, most have spinning problems, while others were just no longer recognized and could not be PREPped. This is a shame considering the shortage of large working MFM hard drives.

Most of the problem drives, and very common among the various models of Seagate MFM drives, is the drive's inability to spin their platters. Often called **'Stiction'**, the problem is generally thought to be caused by the drive's read /write heads becoming stuck to the smooth surface of the media surface during storage or unuse. The problem is particularly susceptible if the drives were heavily used and warm before shutdown. The more heads being used, the greater the probability of becoming stuck to the surface of the platters because of the greater torque needed to be produced by the controller board to break the heads free.

For more information on stiction, please review the article, **'Why Should I 'SHIP' My Hard Drive?'** published in issue #38 of the '*Z-100 LifeLine*'. That was back in March-April, 1995.

It also would not hurt to review these articles:

'More Seagate Drive Problems' from issue #41. It describes my prior efforts to troubleshoot these ST-251 drives - and finding that it was not stiction, but a problem with some of the PROM IC's installed on the drives' attached controller boards.

'Seagate Drive Problems - Continued' from issue #42. It goes into great detail regarding the various PROM's found on the attached controller boards.

- Of particular note, however, of the PROM chips that would not allow the drive to spin, shorting pins 21 and 22 together would start the drive, but only if the drive was clicking at the time. Once started, the drive would spin up to speed and continue. Shorting pins 9 and 10 together would cause the clicking to cease. And touching pin 1 (CLR) of a 74LS273D chip with a grounded lead caused the clicking to resume.

- Also of note, on the boards without a PROM, touching the PROM pin locations #14 and #16 together momentarily at startup would get the drive to spin.

- And finally, on all drives that did not spin, shorting pins 8 & 12 together on the 11791 chip caused the drive to spin, but only while shorted. The drive, however, will not PREP if the pins are left shorted.

'Seagate Drive Problems - Continued' in issue #45. This investigated the various controller board and model ST-251 drive differences. Because of their importance, I will briefly list my findings here:

- Of the six ST-251 and ST-251-1 drives at the time, two had stepper motors with multicolored power leads and four had grey ribbon cable leads.

- Of the nine PROMs at the time, six had completely different programs, and that did not include the two boards that did not have PROMs at all.

- Of the six drive boards, there were 3 different versions and one of those came with and without PROMs - these were marked as assembly #20938 EC.

- The drives with the multi-colored stepper motor leads had stepper motors with 92 positions. The motors with grey ribbon cable leads had 46 positions.

- Both drives with the multi-colored stepper motor leads worked only with the assembly #20938 EC boards with the LSI-L18 labeled PROMs. But this board/PROM combination drove the 46 position grey cable stepper motors nuts with a lot of banging at both ends of travel. Obviously, these drives required a different board/PROM combination.

I concluded that article with a plea for help:

If you have a stock of working or non-working ST-251 drives, could you please send me the following information:

- Stepper motor model - this is found in a corner of the drive opposite the power connector.

- Board ASSY# - found printed on the circuit board beside the stepper motor.

- PROM #, if installed. If there are no pins seen extending through the board on the same side of the board as the cutout for the stepper motor, then don't bother removing the circuit board from the drive - there is no PROM.
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One more article was written on the subject addressing an e-mail from a person familiar with repairing hard drives. Please review the article, '**Seagate Stiction E-mail**', from issue #87, published in May-June 2003.

In it, I discussed my theory about the stiction problem - and adding 47 μF capacitors to the +5vdc and +12vdc power connectors. The motor uses 12v power, but the read/write heads and circuitry use 5v power. While the capacitor on the 5v line may be obvious, adding the extra capacitance to the 12v line would improve read /write operations by smoothing any ripple in the speed of the spindle motor. Any fluctuation in that speed could change the spacing of data placed on the platters very slightly.

That concluded the series I published on the ST-251. Some of the controllers and drives that I could not get to work with anything I scraped. I have also lost track of some of the working board/drive combinations - I assume they are still working in a few of my computers somewhere.

I have found another ST-251 drive since then and I revisited this non-spinning drive issue. Obviously, these drive combinations had worked at some time in the past. Why are they no longer working?

This article documents what I had found during my troubleshooting of these ST-251 40Mb hard drives. I took a different tact though. This time, I dug around at the circuit level in an effort to determine if the drive or the controller board (PROM) was causing the problem.

Let me begin by listing the drives and the boards that I was working with. In addition to three drives that I still had sitting on the shelf, I had a new drive, with the same familiar complaint - no spin, but with the right board configuration; a grey stepper motor ribbon cable and a controller without a PROM installed.

As the new drive came with its original board - one that should work with any of my existing drives, I felt it was imperative that I attempt to get this board to work.

The new ST-251 drive, #01755509 on the label, had the grey stepper motor leads, same as my other three drives. It used a board that I labeled as 'T', was labeled in copper trace: 'Seagate Technology, 251 - LSI FA control, ASSY 20938 EC', and had no PROM.

A working drive that I had on the shelf, #651000007844 on the label, had multi-colored stepper motor leads and used a board I had previously labeled as 'D'. The board was labeled in copper trace: 'Seagate Technology, Control ASSY 20629 REV, 94V-0, 8806'. The board was completely different and had a different PROM. As it worked, I would not be playing further with it.

An inoperative drive, #959708, had grey stepper motor leads, but back in March 2002, was found to work only with board 'W', another board without an PROM that has since disappeared - presumably attached to another working drive somewhere.

An inoperative drive, #26962440, had grey stepper motor leads, presently without a board. According to notes, the drive had a board without an PROM chip, but did not spin due to what I had thought were shorted IRFD110 MOSFET chips. I trashed the board back in June 2012 because the drive spun with another ST-251 board, but had loud clunks and clicks from the stepper motor. I thought it would possibly work with the correct board, so placed it on the shelf. I should have kept the board.

Boards 'A' and 'B', labeled 'Seagate Technology Control, ASSY 20938 EC' in copper trace, and having the LSI L18 PROM installed, permitted any of the non-working drives above to spin, but with the clunks & clicks from the stepper motor (grey leads).

Board 'S' was exactly the same as 'A' and 'B', but had an F18I PROM installed, which did not allow any of the above drives to spin. Whether this was the original PROM, or the result of prior experimentation, I do not remember. It was missing parts and had traces cut to trace circuits for voltage and resistance checks.

I have managed a rough schematic of the pertinent circuit, Drawing 1, that enabled the drive motor to spin and is included as page 4. As the circuit boards do not use silkscreened part numbers, I tried to leave the pertinent parts in their relative positions to assist in location identification. For added clarity, I left out the wiring between parts, preferring to use circuit numbers to tie the various parts together. For example, C12 is one of the circuits connecting the motor connector, 11791 controller, MOSFET's and other parts together. As you can see, it is keyed to the 11791 pin numbers.

To help you troubleshoot your non-spinning Seagate ST-251 hard drive, I have tried to list expected resistances and voltages that you should be able to check. Please keep in mind that these are relevant only for the ASSY 20938 EC labeled circuit boards using the 11791 controller chip. The data should vary for different boards and PROMs. I also include data for boards with and without the PROM installed.

Note: I am using an old RCA VoltOhmyst tube-driven meter for these readings. Resistance checks will vary by the scale set. It is also constantly drifting, so please do not treat these readings as gospel. If you are within 10%, you are probably good.

Controller Board Resistance Checks

All Boards:

* 11791 Controller IC installed
* IRFD110 MOSFET's installed
* No terminator resistor pack installed
* PROM LSI L18 installed
* For the following checks, there were no significant differences between boards, except at 11791 pins 11, 12, & 13, which may appear shorted to ground due to the MOSFET's being left turned on. More on this later.
* On boards 'A' and 'B', the drive spins, but the stepper motor clunks and bangs during initial seek checks.

11791 Forward Resistance Checks: Rx100 scale
(Ground lead to board ground)
(Pin 1 has a square solder pad)

Pin:	Ohms:	Pin:	Ohms:	Pin:	Ohms:
1	1kΩ	8	1kΩ	15	5kΩ
2	0	9	1.2kΩ	16	5kΩ
3	6.5kΩ	10	5kΩ	17	5kΩ
4	980Ω	11	6kΩ	18	5kΩ
5	210Ω	12	6kΩ	19	5kΩ
6	980Ω	13	6kΩ	20	5kΩ
7	0	14	0	21	0

11791 Reverse Resistance Checks: Rx10 scale
(Blue lead to board ground)

Pin:	Ohms:	Pin:	Ohms:	Pin:	Ohms:
1	120 Ω	8	92 Ω	15	140 Ω
2	0	9	128 Ω	16	140 Ω
3	120 Ω	10	70 Ω	17	140 Ω
4	60 Ω	11	66 Ω	18	120 Ω
5	45 Ω	12	66 Ω	19	130 Ω
6	88 Ω	13	66 Ω	20	133 Ω
7	0	14	0	21	0

Note: The following resistance checks were taken at the PROM socket of each board. Again, there were no significant differences, except as noted separately. Resistances were measured with and without the PROM (both LSI L18 and F18I were both checked).

PROM Forward Resistance Checks: Rx100 scale
(Ground lead to board ground)
(Pin 1 has a square solder pad)

Pin:	W/Prom:	W/O:	Pin:	W/Prom:	W/O:
1	∞	∞	13	∞	∞
2	∞	∞	14	∞	∞
3	∞	∞	15	∞	∞
4	∞	∞	16	∞	∞
5	3.8k Ω	3.8k Ω	17	∞	∞
6	4k Ω	4.1k Ω	18	0	0
7	4.4k Ω	4.5k Ω	19	∞	∞
8	5.1k Ω	5.1k Ω	20	1.8k Ω	1.6k Ω
9	∞	∞	21	∞	∞
10	∞	∞	22	∞	∞
11	∞	∞	23	∞	∞
12	0	0	24	220 Ω	240 Ω

Note: When comparing forward resistances at the PROM socket while comparing board 'B', which required a PROM, with Board 'T' which had no PROM, there were no significant differences.

PROM Reverse Resistance Checks: Rx10 scale
(Blue lead to board ground)

Pin:	W/Prom:	W/O:	Pin:	W/PROM:	W/O:
1	102 Ω	102 Ω	13	65 Ω	68 Ω
2	102 Ω	102 Ω	14	65 Ω	68 Ω
3	102 Ω	102 Ω	15	65 Ω	68 Ω
4	102 Ω	102 Ω	16	65 Ω	68 Ω
5	270 Ω	330 Ω	17	65 Ω	68 Ω
6	67 Ω	68 Ω	18	0	0
7	67 Ω	68 Ω	19	102 Ω	102 Ω
8	65 Ω	68 Ω	20	83 Ω	102 Ω
9	65 Ω	68 Ω	21	102 Ω	102 Ω
10	65 Ω	68 Ω	22	102 Ω	102 Ω
11	65 Ω	68 Ω	23	102 Ω	102 Ω
12	0	0	24	48 Ω	50 Ω

Note: When comparing reverse resistances at the PROM socket between board 'B' which required a PROM, but which is removed, with Board 'T' which had no PROM, there were significant differences because a support chip, LS373, was also not installed on board 'T'. The results follow:

PROM Reverse Resistance Checks: Rx10 scale
(Blue lead to board ground)
(Pin 1 has a square solder pad)

Pin:	'B':	'T':	Pin:	'B':	'T':
1	102 Ω	∞	13	68 Ω	95 Ω
2	102 Ω	∞	14	68 Ω	98 Ω
3	102 Ω	∞	15	68 Ω	98 Ω
4	102 Ω	∞	16	68 Ω	98 Ω
5	330 Ω	320 Ω	17	68 Ω	98 Ω
6	68 Ω	74 Ω	18	0	0
7	68 Ω	74 Ω	19	102 Ω	∞
8	68 Ω	74 Ω	20	102 Ω	94 Ω
9	68 Ω	100 Ω	21	102 Ω	∞
10	68 Ω	95 Ω	22	102 Ω	∞
11	68 Ω	99 Ω	23	102 Ω	∞
12	0	0	24	50 Ω	48 Ω

Finally, I also checked the pin resistances of the 11791 controller integrated circuits that I had removed from several boards in the past for comparison purposes.

Note: With the IC placed on its front with pins towards you, Pin 1 is the right-most pin. Remember, these are out-of-circuit resistances.

11791 Forward Resistance Checks: Rx100 scale
(Ground lead to chip ground)

Pin:	Ohms:	Pin:	Ohms:	Pin:	Ohms:
1	1kΩ	8	3kΩ	15	5.5kΩ
2	30Ω	9	∞	16	5.5kΩ
3	7kΩ	10	20kΩ	17	5.5kΩ
4	1.8kΩ	11	8kΩ	18	5.5kΩ
5	4kΩ	12	8kΩ	19	5.5kΩ
6	5kΩ	13	8kΩ	20	5.5kΩ
7	7kΩ	14	0	21	40Ω

11791 Reverse Resistance Checks: Rx10 scale
(Blue lead to chip ground)

Pin:	Ohms:	Pin:	Ohms:	Pin:	Ohms:
1	260 Ω	8	400 Ω	15	240 Ω
2	260 Ω	9	400 Ω	16	240 Ω
3	250 Ω	10	170 Ω	17	240 Ω
4	180 Ω	11	75 Ω	18	230 Ω
5	350 Ω	12	75 Ω	19	235 Ω
6	350 Ω	13	75 Ω	20	235 Ω
7	400 Ω	14	0	21	0

Note: These reverse resistances varied greatly between chips, as much as 200 ohms from the average, especially with the two 11791-002 chips. So, for the 11791 chips, I give an average. Is higher or lower better? I do not know.

Controller Board Voltage Checks
Finally, I did some DC voltage checks. These were taken a various points in the circuit of Drawing 1 and measured from board ground. The voltages on the drawing are those of a working drive. But, as we are mostly interested in the motor connector, I will list them separately here.

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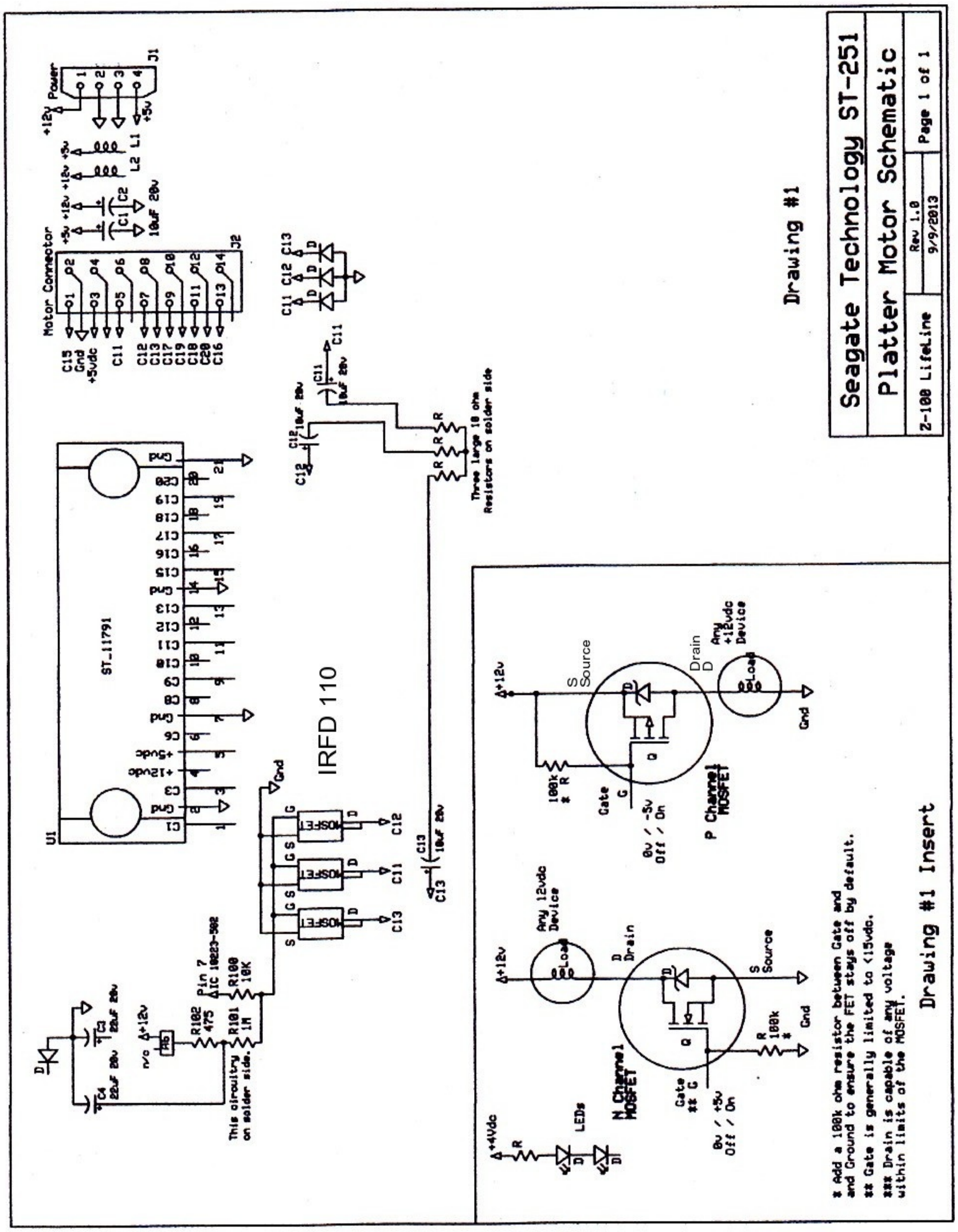
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Motor Connector DC Voltages

	Pin:	Pin:	
+2.5v	0 1	2 0	0
+5v	0 3	4 0	+7-8v
+7-8v	0 5	6 x	0 (n/c)
+7-8v	0 7	8 0	+7-8v
+2.5v	0 9	10 0	+2.5v
+2.5v	0 11	12 0	+2.5v
+2.5v	0 13	14 0	0

On those boards that do not spin the drive, pins 3, 4, 11, & 13 measure about .6 volts!

I also checked the MOSFET voltages, as these tended to show direct shorts from the Drain to the Source (ground) during the resistance checks.

MOSFET Voltages	
Source (ground)	0
Gate	0.15v
Drain	+7.7vdc

The drain voltages would be 0.55-0.72v on the non-working boards.

I have also tabulated the data by pin-out on the 11791 controller for the spinning versus non-spinning drives so you can see the differences:

Circ/ Pin#:	**Non-Spin:**	**Circ/ Spin:**	**Non-Pin#:**	**Spin:**	**Spin:**
C1	1.2v	1.25v	C11	7.8v	<4v
C2	Gnd	Gnd	C12	7.8v	<4v
C3	3.6v	0	C13	7.8v	<4v
C4	+12vdc	+12vdc	C14	Gnd	Gnd
C5	+5vdc	+5vdc	C15	2.5v	2.5v
C6	1.8v	1.8v	C16	2.5v	2.5v
C7	Gnd	Gnd	C17	2.5v	2.5v
C8	3.8v	0.2v	C18	2.5v	2.5v
C9	1.0v	0.2v	C19	2.5v	2.5v
C10	12.5v	12.5v	C20	2.5v	2.5v
			C21	Gnd	Gnd

As the PROM 2732 is also a significant part of this mystery, I have added the pinout connections below. There may be additional connections that I did not detect. The pins are identified as P1 through P24 and the pin numbers of connecting IC's are in parentheses (). Also shown is the voltage to ground if a PROM is installed and the drive is spinning:

Pin#:	**Connections:**	**Voltage:**
P1	LS373 (12)	3.7v
P2	LS373 (16)	3.7v
P3	LS373 (15)	3.7v
P4	LS373 (19)	3.7v
P5	IC 10219 (8)	4.9v
P6	IC 10219 (7)	4.9v
P7	IC 10219 (6)	4.9v
P8	IC 10219 (5)	4.9v
P9	IC 10219 (20), LS273 (18), LS373 (18)	3.7v
P10	IC 10219 (19), LS273 (14), LS373 (14)	3.7v
P11	IC 10219 (18), LS273 (17), LS373 (17)	3.7v
P12	Ground	0.0v
P13	IC 10219 (17), LS273 (13), LS373 (13)	3.7v
P14	IC 10219 (16), LS273 (3), LS373 (3)	3.7v
P15	IC 10219 (15), LS273 (8), LS373 (8)	3.7v
P16	IC 10219 (14), LS273 (7), LS373 (7)	3.7v
P17	IC 10219 (13), LS273 (4), LS373 (4)	3.7v
P18	Ground	0.0v
P19	LS373 (6)	3.7v
P20	74F10 (8)	4.4v
P21	LS373 (5)	3.7v
P22	LS373 (9)	3.7v
P23	LS373 (2)	3.7v
P24	Vcc, +5Vdc	5.0v

Note: On boards without a PROM installed, the integrated circuit 74LS373 is also missing. Nevertheless, I also tried board 'T' on the same drive, which did not spin. The differences in voltages were considerable. I did not include them in the table because the drive was not spinning, so it was not a normal condition. The voltages are summarized here:

- Pins 1, 2, 3, 4, 19, 21, 22, 23: As the 74LS373 was missing, any connections to only that IC all had zero volts; consider as normal.

- Pins 9, 10, 11, 13, 14, 15, 16, 17: All measured 1.8v which may be caused by the missing 74LS373.

- All other pins were as expected.

Finally, I did not complete the testing. I was going to recheck the results of shorting various pins on the PROM and 11791 Controller chip that I had listed back on page 1 next, see if all the voltages reflected the drive beginning to spin, and see if I could find some explanation.

- Of particular note, however, of the PROM chips that would not allow the drive to spin, shorting pins 21 and 22 together would start the drive, but only if the drive was clicking at the time. Once started, the drive would spin up to speed and continue. Shorting pins 9 and 10 together would cause the clicking to cease. And touching pin 1 (CLR) of a 74LS273D chip with a grounded lead caused the clicking to resume.

- Also of note, on the boards without a PROM, touching the PROM pin locations #14 and #16 together momentarily at startup would get the drive to spin.

- Finally, on all drives that did not spin, shorting pins 8 & 12 together on the 11791 chip caused the drive to spin, but only while shorted. The drive, however, would not PREP if the pins are left shorted.

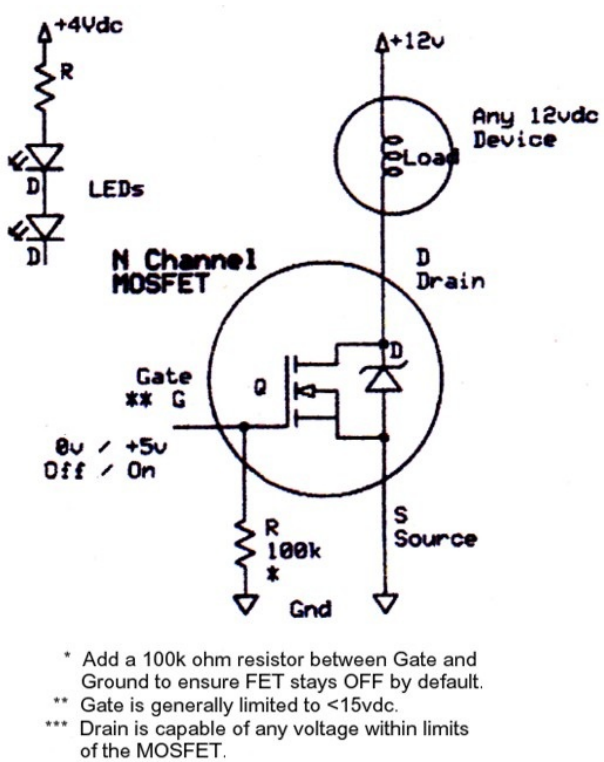
The MOSFETs

All of my controller boards used IRFD110 N-channel MOSFET's to control the motor spinning.

As I mentioned earlier, back in June 2012 while I was troubleshooting these boards, the extremely low drain voltages on the non-working boards caused great speculation on my part and I jumped on these as the problem. On one board I would measure the resistance from the drain to ground and find each of them (there are three) shorted out both ways! However, upon removal of the first, it would then test fine. Removal of the second, did the same. And finally, removal of the third also did the same! If you were to reinstall them, they would now seem fine - no shorts!

I ended up trashing a controller board after puzzling over this for some time.

Well, this time I researched MOSFET's on the web and found the following. To help understand the use of an N-channel MOSFET to control a load, such as a motor, I have included a simplified drawing (Drawing 2), that I found on the web.



Drawing #2

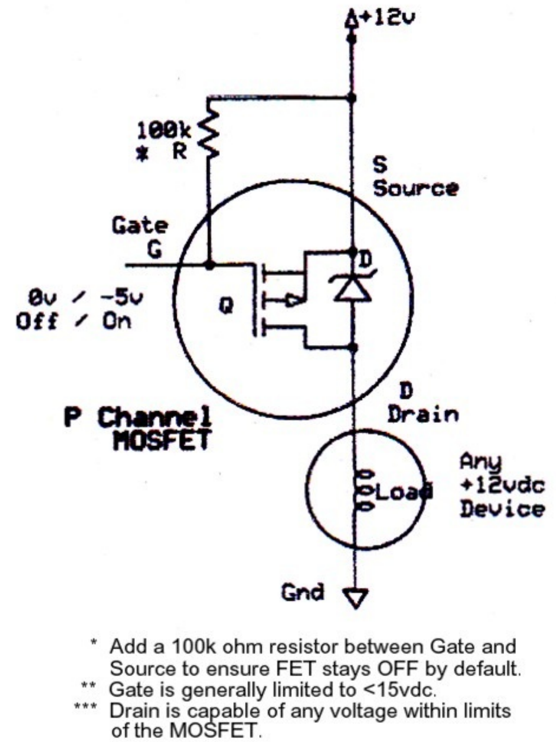
As you can see from the drawing, the N channel MOSFET acts like a relay, controlling the ON/OFF of a different (not necessarily higher) voltage load using low voltage control. The MOSFET can be either N-channel or P-channel and uses three leads, the Drain, the Source, and the Gate. As we are using the N-channel version, the following description will concentrate on that. However, for comparison purposes, the P-channel version is shown in Drawing #3.

Note: The IRFD110 MOSFET's installed on our controller boards are rated for use with the Gate to Source voltage, Vgs, limited to 10v maximum and the Drain to Source voltage, Vds, limited to 100v maximum. Our boards use +5v and +12v, well within limits, and unlikely to be causing problems on our boards.

According to these specifications, the load device attached to our IRFD110 MOSFET could be rated for anything up to 100 volts, if needed. The Gate turns the MOSFET ON at +5vdc. Also, note that a 100k ohm resistor is recommended to ensure that when the circuit controlling the Gate is OFF, the 100k ohm resistor bleeds the voltage to zero, ensuring that the Gate is OFF.

Note: The voltage being controlled need NOT be higher than the Gate's controlling voltage. In the upper left corner of our drawing I show an alternate load; two LEDs using a +4v voltage source and voltage dropping resistor.

For comparison, the P-channel MOSFET is shown in Drawing #3:



Drawing #3

Note: The P-channel MOSFET uses 0v and -5vdc at the Gate to turn OFF and ON respectively. The resistor in this case is tied to the +12v supply to ensure the Gate is OFF and at a positive voltage, thus ensuring the MOSFET is OFF.

Back to reality, our circuit is not nearly this simple. However, armed with this information, we can see that if the MOSFET is left ON when power is removed, the MOSFET internal resistance can appear to be nearly zero - both ways. Through experimentation, I found that the motor will indeed still spin properly with these MOSFET's seemingly shorted.

In addition, on the boards that do permit the drives to spin, I found that the drives will still spin with the MOSFET's completely removed! Our non-spin problem must be elsewhere.

If I ever resume testing, I wish to recheck the results of shorting various pins on the PROM and 11791 Controller chip that I listed back on page 1 next, see if all the voltages reflected the drive beginning to spin, and see if I could find some explanation.

I hope you find this exercise helpful.

Cheers,