

The 1974 Smiths Seat Belt Module

Reverse Engineering Information



Revision 1.2

Mark Olson

www.accutach.com

1974 Smiths Seatbelt Module Reverse Engineering Information

This is what the 1974 Series-3 E-type Jaguar Smiths Seat Belt Module looks like prior to disassembly:



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In 1974, the US Federal Government mandated that car starters be disabled if seated drivers did not have their seat belts fastened. This unpopular requirement only lasted for one year, so there are not many cars left with the electronics required to implement the function.

One type of seat belt module that is of particular interest is the Smiths module, made in the UK. It was used in the 1974, Series-3, E-type V12 Jaguars, at least some Triumph models and other British sports cars. Restoration purists will want these modules repaired if they break.

Dick Wells asked me to take a look at one of his 1974 Jaguar units to see what I could learn.

This document contains what I have learned in the process.

The Intent of the Module

The module is intended to prevent the driver from starting the car unless each person sitting in the car has fastened his/her seat belt. Once the car has been started, it is possible to restart the car, regardless of the seating and seat belt conditions. This prevents the unfortunate experience of being unable to start a stalled car in an inconvenient spot such as on a railroad track.

It also provides the buzzer function if the car door is opened with the key still in the ignition.

The Design of the Module.

The heart of the module is a custom 16-pin Texas Instruments logic integrated circuit, probably implemented in MOS technology. The chip is labeled, "MIC7/C".

The module has a 12 pin interface to the car, with 4 pins supplying 12V: Hot-in-Run, Hot-At-All-Times, Hot-in-Start and Hot-When-in-Gear. It appears from the design that the majority of the power to the IC is supplied via the Hot-in-Run pin.

One module pin supplies ground for the module, 5 pins provide active-low inputs to the module and two pins provide the output functions: Enable Starter and Light the Fasten Seat Belt Indicator.

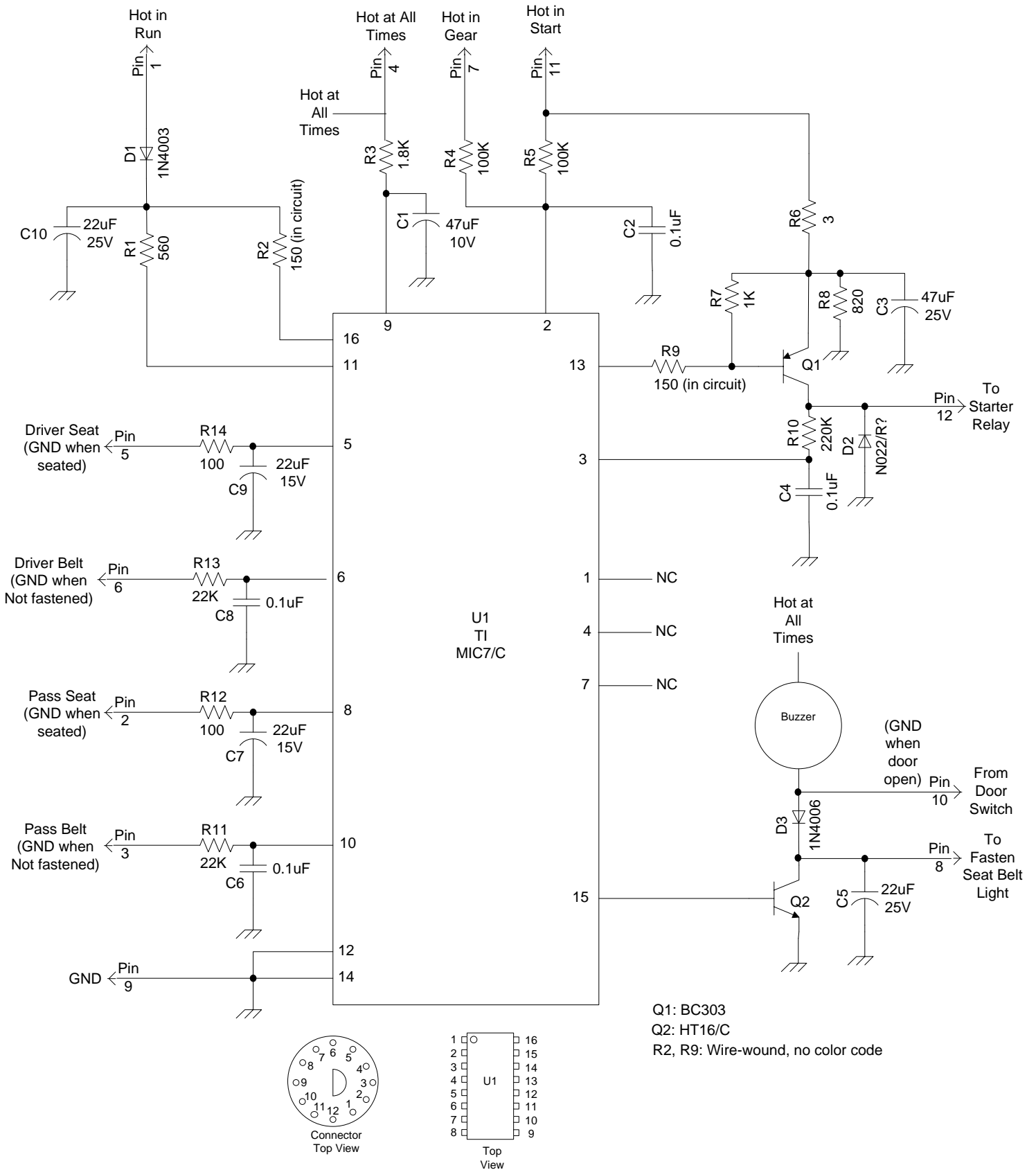
All of the inputs other than the Door-open input employ an RC network, which I presume is a cheap way to debounce the inputs. It may also provide some ESD protection for the IC's inputs. Some of the inputs (such as the Seated inputs, use large electrolytic capacitors which may also delay the signals by up to one second.)

The output of the IC that drives the starter relay goes to a BC303 PNP bipolar driver transistor which switches power to the relay. There is a snubber diode (D2) that prevents back EMF from the relay coil to damage the PNP driver transistor. That diode is marked "N022/R". I have not been able to find any information about that diode other than the opinion that it may be a Shottkey diode.

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1974 Smiths Seatbelt Module Schematics

Mark Olson
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The output of the IC that drives the buzzer and the Fasten Seat Belt light is an NPN bipolar driver transistor that switches ground for both the buzzer and the Fasten Seat Belt light. The transistor is marked "HT16/C", and I have not been able to find any information about that transistor. There is a 1N4006 diode that isolates the Fasten Seat Belt light output from the door switch input. This means that the door switch will only drive the buzzer, not the Fasten Seat Belt light.

The IC logic implements what appears to be a two-state state-machine, probably implemented with a flip-flop. The initial state is "Starter Disabled" and the other state is "Starter Enabled". The state switches to Starter Enabled when the correct order of sitting, belting, key on and starter signal is executed. The transition to the Starter Disabled state occurs whenever the driver's seat is empty, and the ignition switch (both Run and Start) are off. FYI, the Starter relay output is fed back into the IC, which I presume sets the state relay to Starter Enabled state.

Design of a Module Tester

A module tester was needed in order to test the module as well as to be able to infer the logic implemented in the custom TI chip. The tester needed to be able to supply power and ground for the module, as well as simulated Seat, Belt and Door sensors. I needed to understand the function of the ignition switch, the transmission switch, the seat switches, the belt switches and the neutral switch. Thanks to help from Dick Wells, I was able to determine the following:

- The Ignition switch Run output provides battery power when in Start or Run
- The ignition switch Start output provides battery power when in Start
- The ignition switch Door Circuit provides ground for the door buzzer when the key is in the ignition
- The Neutral switch provides battery power whenever the transmission is NOT in neutral
- Each Seat switch provides ground when a person is seated
- Each Belt switch provides ground when the seat belt is NOT fastened
- The Door Switch provides ground when the key is in the ignition AND either door is open
- I added a switch in the Hot-at-all-Times circuit to simulate a broken wire.

After determining that simple SPDT switches were all that were needed to control power and inputs, I designed two simple LED circuits, one green for the Starter Enabled output, and one red for the Fasten Seat Belt light. I used a 620 ohm resistor in series with each LED to limit the current to the LEDs to near their typical spec of 20mA.

I found some Molex style female pins that fit the connector at a Silicon Valley junk shop, so I just soldered them to the numbered wires from the tester. It is important that you plug the correct pins together or you can destroy the tester and/or the module.

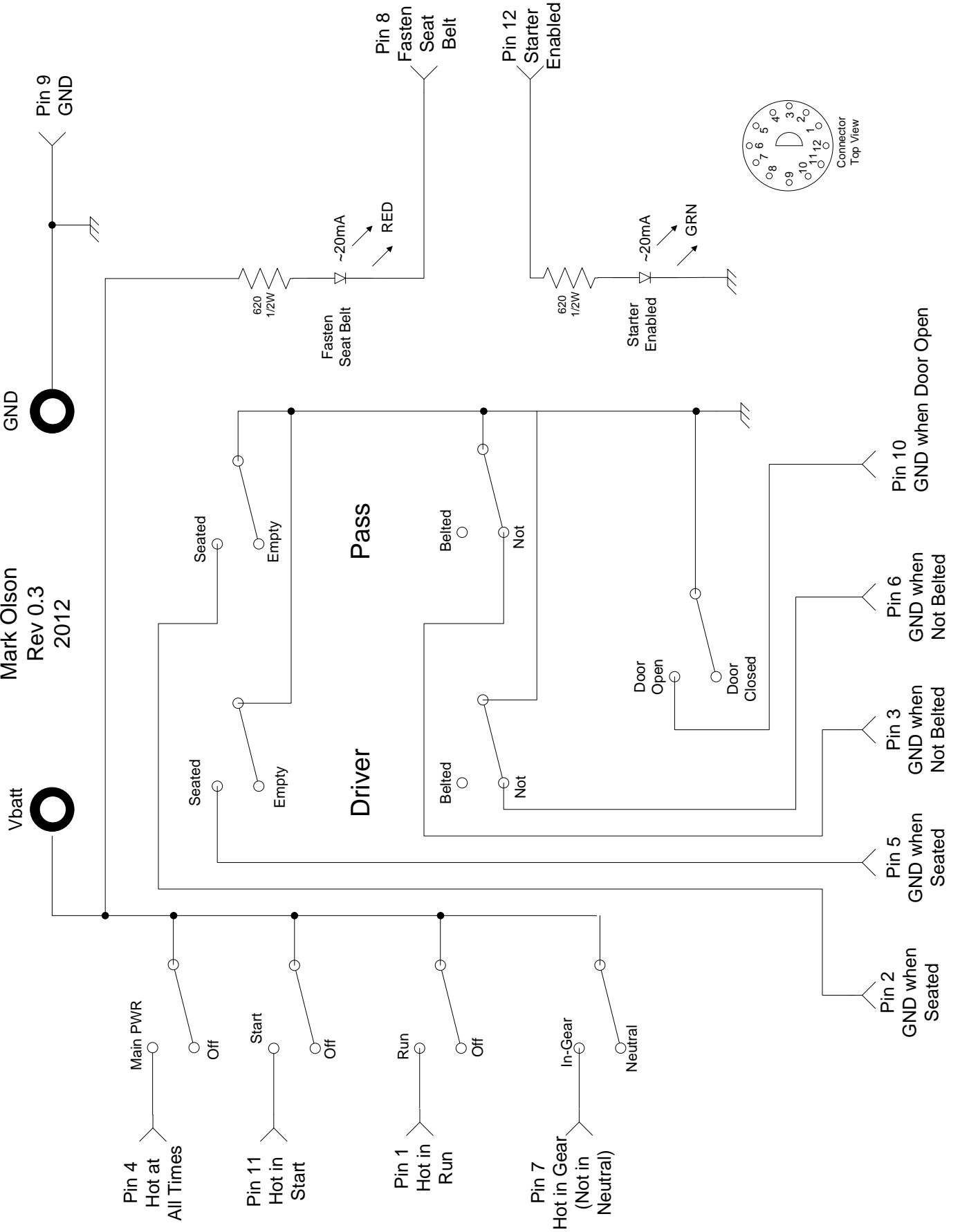
While debugging the tester, I learned that the module's buzzer was shorted, and non-functional. I had to remove it from the circuit to test it. I learned that it drew 1.14A when connected to a 12V bench supply, and it got hot. It drew so much current that it reduced the voltage of the entire module until the module no longer worked. So whenever the Fasten Seat Belt Light signal went live, the unit would stop working correctly until the Fasten Seat Belt light turned off. Once I removed the buzzer from the circuit, the module began to work properly, minus the buzzing sound.

The following pages have the schematics and pictures of the tester

1974 Smiths Seatbelt Module Reverse Engineering Information

1974 Jaguar Seat Belt Module Tester

Mark Olson
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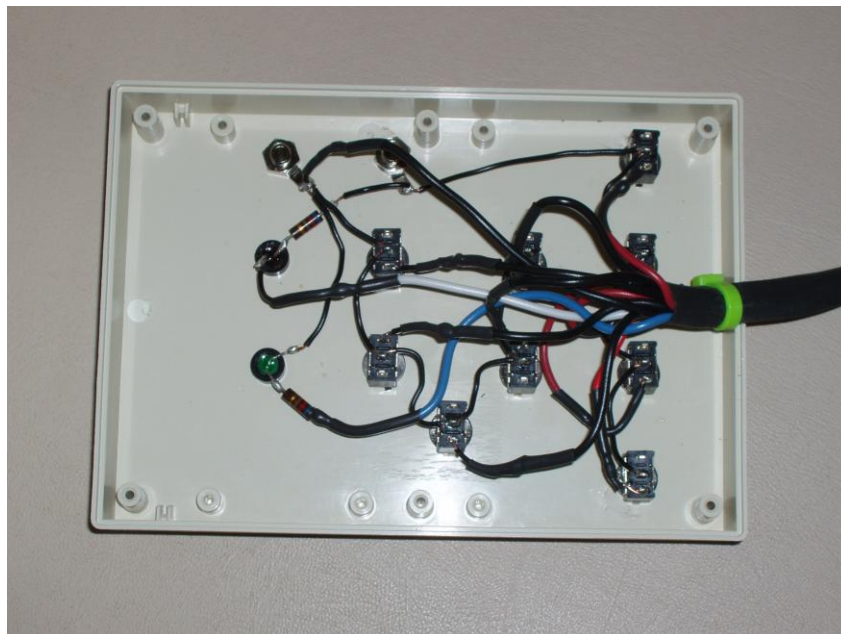


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I bought a plastic box from LMB for the project. The model number is: 504. I laid out the switch locations like below to avoid interference from the battery enclosure in the bottom of the box.

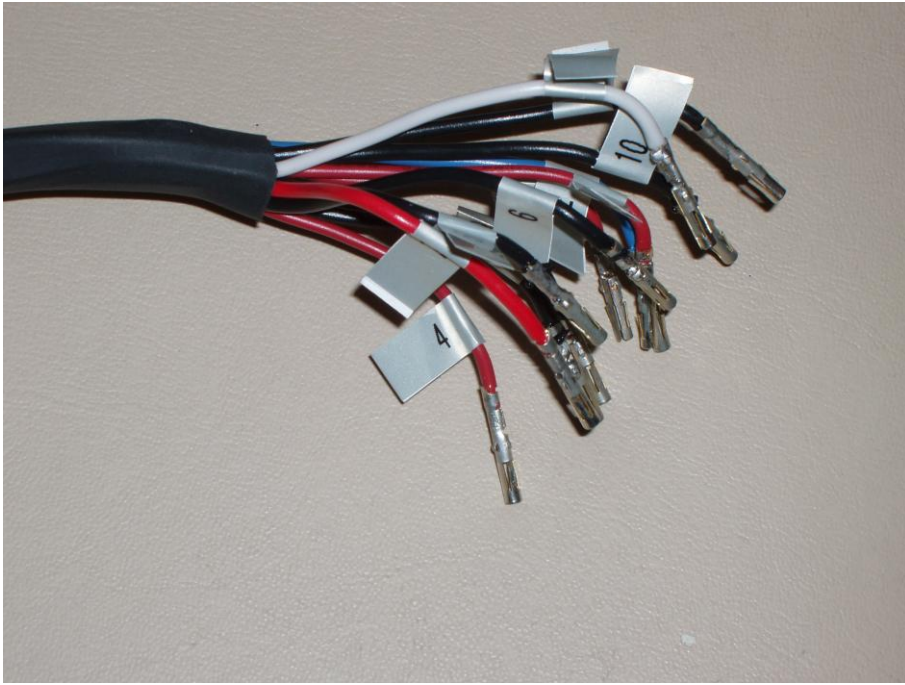


I used standard mini toggle switches with $\frac{1}{4}$ " mounting holes. They are not center-off switches. I used SPDT switches to make debugging the tested design easier, but you can use SPST switches. I also used some standard, small LED and LED mounting bezels that I had laying around. I drilled a hole for the wire bundle that goes to the module, shrink wrapped the bundle and put a zip tie on it for strain relief:

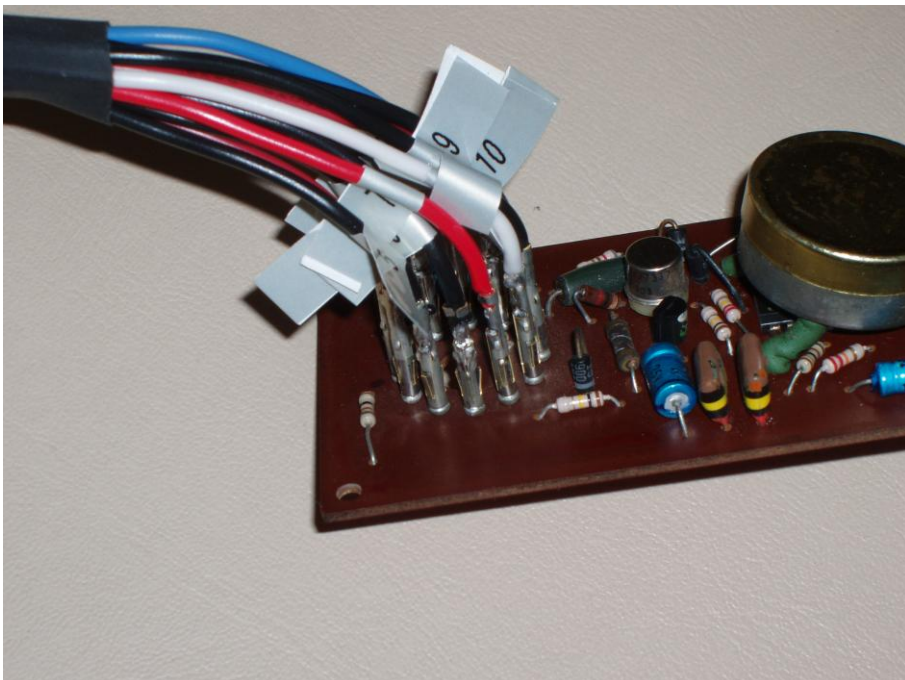


1974 Smiths Seatbelt Module Reverse Engineering Information

I soldered the female Molex style pins to the wires that connect the tester to the module. I numbered each connector with the corresponding module connector pin number:



Here is a picture of the connectors on the module connector. Be very careful to ensure you connect the pins correctly or damage to the tester and/or the module can occur. For added safety, I used red wires for the battery power pins, black ones for the ground pins, a white wire for the Fasten Seat Belt signal and a blue wire for the Starter Enabled signal.



Connecting a regulated nominal 12V power supply (10-15VDC) is all that remains before starting testing. (A charged car or motorcycle battery works fine.)

Module Logic

After I got the tester built and debugged, and the module working, it was time to determine the logic implemented in the module. It is interesting to note that the module still works even if the Hot-at-all-Times power is turned off.

I did a rigorous recording of the logic so that a future electrical engineer can build a replacement chip and/or module should the supply of these units dry up.

The following pages contain the analysis of the logic of the module.

Remember, the module is a two-state state-machine. The two states are:

State 1: Starter Disabled State

State 2: Starter Enabled State

The Module goes from the Starter Disabled State to the Starter Enabled State when the logic in State 1 enables the starter.

The module goes from the Starter Enabled State to the Starter Disabled State when the logic in State 2 shows Start is OFF AND Run is OFF AND the Driver is NOT Seated.

1974 Smiths Seatbelt Module Reverse Engineering Information

State 1: Starter Disabled

Main	Run	Start	In	Driver	Driver	Pass	Pass	Belt Light	Starter	
Power On	On	On	Neutral	Seated	Belted	Seated	Belted	& Buzzer	Enabled	
No	No	X	X	X	X	X	X	Off	Off	
No	Yes	No	No	No	No	No	No	Off	Off	
No	Yes	No	No	No	No	No	Yes	Off	Off	
No	Yes	No	No	No	No	Yes	No	On	Off	
No	Yes	No	No	No	No	Yes	Yes	Off	Off	
No	Yes	No	No	No	Yes	No	No	Off	Off	
No	Yes	No	No	No	Yes	No	Yes	Off	Off	
No	Yes	No	No	No	Yes	Yes	No	On	Off	
No	Yes	No	No	No	Yes	Yes	Yes	Off	Off	
No	Yes	No	No	Yes	No	No	No	On	Off	
No	Yes	No	No	Yes	No	No	Yes	On	Off	
No	Yes	No	No	Yes	No	Yes	No	On	Off	
No	Yes	No	No	Yes	No	Yes	Yes	Off	Off	Note 1
No	Yes	No	No	Yes	Yes	No	No	Off	Off	Note 1
No	Yes	No	No	Yes	Yes	No	Yes	Off	Off	Note 1
No	Yes	No	No	Yes	Yes	Yes	No	On	Off	
No	Yes	No	No	Yes	Yes	Yes	Yes	Off	Off	
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No	Yes	No	Yes	No	No	Yes	Yes	Off	Off	
No	Yes	No	Yes	No	Yes	No	No	Off	Off	
No	Yes	No	Yes	No	Yes	No	Yes	Off	Off	
No	Yes	No	Yes	No	Yes	Yes	No	Off	Off	
No	Yes	No	Yes	No	Yes	Yes	Yes	Off	Off	
No	Yes	No	Yes	Yes	No	No	No	Off	Off	
No	Yes	No	Yes	Yes	No	No	Yes	Off	Off	
No	Yes	No	Yes	Yes	No	Yes	Yes	Off	Off	
No	Yes	No	Yes	Yes	Yes	No	No	Off	Off	
No	Yes	No	Yes	Yes	Yes	No	Yes	Off	Off	
No	Yes	No	Yes	Yes	Yes	Yes	No	Off	Off	
No	Yes	No	Yes	Yes	Yes	Yes	Yes	Off	Off	
No	Yes	Yes	No	No	No	No	No	Off	On	->S2*
No	Yes	Yes	No	No	No	No	Yes	Off	On	->S2*
No	Yes	Yes	No	No	No	Yes	No	On	Off	
No	Yes	Yes	No	No	No	Yes	Yes	Off	On	->S2*
No	Yes	Yes	No	No	Yes	No	No	Off	On	->S2*
No	Yes	Yes	No	No	Yes	No	Yes	Off	On	->S2*
No	Yes	Yes	No	No	Yes	Yes	No	On	Off	
No	Yes	Yes	No	No	Yes	Yes	Yes	Off	On	->S2*
No	Yes	Yes	No	Yes	No	No	No	On	Off	
No	Yes	Yes	No	Yes	No	No	Yes	On	Off	
No	Yes	Yes	No	Yes	No	Yes	No	On	Off	
No	Yes	Yes	No	Yes	No	Yes	Yes	On	Off	

1974 Smiths Seatbelt Module Reverse Engineering Information

State 1: Starter Disabled

Main Power On	Run On	Start On	In Neutral	Driver Seated	Driver Belted	Pass Seated	Pass Belted	Belt Light & Buzzer	Starter Enabled	
Yes	Yes	No	Yes	Yes	No	No	No	Off	Off	
Yes	Yes	No	Yes	Yes	No	No	Yes	Off	Off	
Yes	Yes	No	Yes	Yes	No	Yes	No	Off	Off	
Yes	Yes	No	Yes	Yes	No	Yes	Yes	Off	Off	
Yes	Yes	No	Yes	Yes	Yes	No	No	Off	Off	
Yes	Yes	No	Yes	Yes	Yes	No	Yes	Off	Off	
Yes	Yes	No	Yes	Yes	Yes	Yes	No	Off	Off	
Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Off	Off	
Yes	Yes	Yes	No	No	No	No	No	Off	On	->S2*
Yes	Yes	Yes	No	No	No	No	Yes	Off	On	->S2*
Yes	Yes	Yes	No	No	No	Yes	No	On	Off	
Yes	Yes	Yes	No	No	No	Yes	Yes	Off	On	->S2*
Yes	Yes	Yes	No	No	Yes	No	No	Off	On	->S2*
Yes	Yes	Yes	No	No	Yes	No	Yes	Off	On	->S2*
Yes	Yes	Yes	No	No	Yes	Yes	No	On	Off	
Yes	Yes	Yes	No	No	Yes	Yes	Yes	Off	On	->S2*
Yes	Yes	Yes	No	Yes	No	No	No	On	Off	
Yes	Yes	Yes	No	Yes	No	No	Yes	On	Off	
Yes	Yes	Yes	No	Yes	No	Yes	Yes	On	Off	
Yes	Yes	Yes	No	Yes	No	Yes	Yes	On	Off	
Yes	Yes	Yes	No	Yes	Yes	No	No	Off	On	->S2*
Yes	Yes	Yes	No	Yes	Yes	No	Yes	Off	On	->S2*
Yes	Yes	Yes	No	Yes	Yes	Yes	No	On	Off	
Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Off	On	->S2*
Yes	Yes	Yes	Yes	No	No	No	No	Off	On	->S2*
Yes	Yes	Yes	Yes	No	No	No	Yes	Off	On	->S2*
Yes	Yes	Yes	Yes	No	No	Yes	No	On	Off	
Yes	Yes	Yes	Yes	No	No	Yes	Yes	Off	On	->S2*
Yes	Yes	Yes	Yes	No	Yes	No	No	Off	On	->S2*
Yes	Yes	Yes	Yes	No	Yes	No	Yes	Off	On	->S2*
Yes	Yes	Yes	Yes	No	Yes	Yes	No	On	Off	
Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Off	On	->S2*
Yes	Yes	Yes	Yes	Yes	No	No	No	On	Off	
Yes	Yes	Yes	Yes	Yes	No	No	Yes	On	Off	
Yes	Yes	Yes	Yes	Yes	No	Yes	No	On	Off	
Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	On	Off	
Yes	Yes	Yes	Yes	Yes	Yes	No	No	Off	On	->S2*
Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Off	On	->S2*
Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	On	Off	
Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Off	On	->S2*

1974 Smiths Seatbelt Module Reverse Engineering Information

Legend

State 1 is Starter Not Enabled. State 2 is Starter Enabled.									
->S1 means that the system transitions to State 1									
->S2 means that the system transitions to State 2									
* Dependent on switch order.									
If the seatbelt switch is set before the seated switch is, then the lights are: On. Off and the state is not changed.									
** Not dependent on order									
*** Dependent on switch order if the Run switch is set first.									
If the seatbelt switch is set before the seated switch is, then the lights are: On. Off and the state is not changed.									
Note 1: Off, Off unless the order is Run, Belt, seated; then On, Off									
X = don't care									

State 1: Starter Disabled

1974 Smiths Seatbelt Module Reverse Engineering Information

State 2: Starter Enabled

Main Power On	Run On	Start On	In Neutral	Driver Seated	Driver Belted	Pass Seated	Pass Belted	Belt Light & Buzzer	Starter Enabled	
No	No	No	X	No	X	X	X	Off	Off	->S1
No	No	No	X	Yes	X	X	X	Off	Off	
No	No	Yes	X	X	X	X	X	Off	Off	
No	Yes	No	No	No	No	No	No	Off	Off	
No	Yes	No	No	No	No	No	Yes	Off	Off	
No	Yes	No	No	No	No	Yes	No	On	Off	
No	Yes	No	No	No	No	Yes	Yes	Off	Off	
No	Yes	No	No	No	Yes	No	No	Off	Off	
No	Yes	No	No	No	Yes	No	Yes	Off	Off	
No	Yes	No	No	No	Yes	Yes	No	On	Off	
No	Yes	No	No	No	Yes	Yes	Yes	Off	Off	
No	Yes	No	No	Yes	No	No	No	On	Off	
No	Yes	No	No	Yes	No	No	Yes	On	Off	
No	Yes	No	No	Yes	No	Yes	No	On	Off	
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No	Yes	No	No	Yes	Yes	No	No	Off	Off	
No	Yes	No	No	Yes	Yes	No	Yes	Off	Off	
No	Yes	No	No	Yes	Yes	Yes	No	On	Off	
No	Yes	No	No	Yes	Yes	Yes	Yes	Off	Off	
No	Yes	No	Yes	No	No	No	No	Off	Off	
No	Yes	No	Yes	No	No	No	Yes	Off	Off	
No	Yes	No	Yes	No	No	Yes	No	Off	Off	
No	Yes	No	Yes	No	No	Yes	Yes	Off	Off	
No	Yes	No	Yes	No	Yes	No	No	Off	Off	
No	Yes	No	Yes	No	Yes	No	Yes	Off	Off	
No	Yes	No	Yes	No	Yes	Yes	No	Off	Off	
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No	Yes	No	Yes	Yes	Yes	Yes	Yes	Off	Off	
No	Yes	No	Yes	Yes	Yes	Yes	No	Off	Off	
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No	Yes	Yes	No	No	Yes	Yes	No	On	On	
No	Yes	Yes	No	No	Yes	Yes	Yes	Off	On	
No	Yes	Yes	No	Yes	No	No	No	On	On	
No	Yes	Yes	No	Yes	No	No	Yes	On	On	

Legend

State 1 is Starter Not Enabled. State 2 is Starter Enabled.							
->S1 means that the system transitions to State 1							
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If the seatbelt switch is set before the seated switch is, then the lights are: On. Off and the state is not changed.							
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*** Dependent on switch order if the Run switch is set first.							
If the seatbelt switch is set before the seated switch is, then the lights are: On. Off and the state is not changed.							
Note 1: Off, Off unless the order is Run, Belt, seated; then On, Off							

State 2: Starter Enabled

74 Jagual Seat Belt Buzzer

I cut the lid off the dead buzzer to see what was inside:



It is interesting to note that the internals of the buzzer are all potted and glued together with green epoxy. I had suspected that the buzzer was a mechanical buzzer, but it turned out to be an electronic buzzer. Here is a side view:

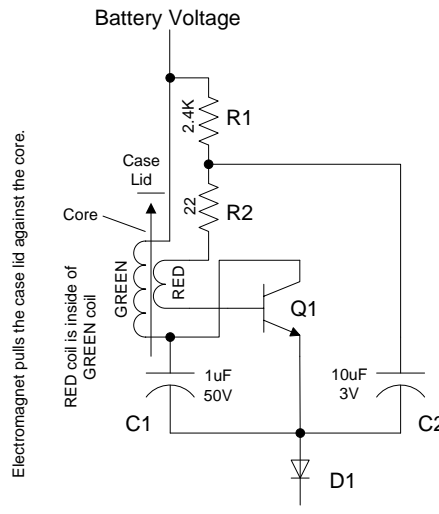


74 Jagal Seat Belt Buzzer

I carefully removed most of the epoxy, to reveal the circuit plus the fact that the coils consist of a green coil on the outside and a red coil on the inside:



The circuit is a one-transistor oscillator that drives an electromagnet on and off. The oscillating electromagnet pulls on the top of the case, using the ferrous top of the case as a speaker for the buzzer. It is interesting to note that the top of the case is the only moving part in the buzzer. Here is the circuit:



When the negative lead is pulled low, Q1 is turned on, driving the electromagnet, pulling the case top down. The feedback circuit driving the base of the transistor turns the transistor off, which turns the electromagnet off, releasing the case top. The feedback circuit turns the electromagnet back on, and so on.