Contact Bounce of a Relay

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Abstract:

Electromechanical relays use an electromagnet to close or open electrical contacts. A common example of a relay is the starter relay an automobile engine. When the driver turns the key fully clockwise in the ignition/starter switch on the steering column, a small current (5 to 10 amps) is sent to a hefty starter relay. Sometimes this relay is an integral part of the starter motor, other times it is mounted elsewhere. You can always tell where the starter relay is, as there is a large diameter wire going from the battery + terminal to the starter relay.

When the small current flows through the relay's coil, a magnetic field is created which attracts a movable iron plate called an armature. The relay armature begins moving, and in a fraction of a second the electrical contact at the end of the armature touches a fixed contact, completing the electrical circuit between the battery and the starter motor. A rather large amount of current, typically 200 to 400 amps, flows into the starting motor and the engine begins to spin. In this way the starter relay remotely turns on the starter motor, reducing both the size of the wire running to the steering column and the cost and size of the steering column-mounted ignition/starter switch.

Equipment:

- Agilent 54600 - Series Oscilloscope
- Agilent E3631A Power Supply

Circuit Explanation:

The relay coil is designed to operate on 12 VDC. Voltage is applied to the relay coil by closing the SPST switch connected to the supply voltage. The oscilloscope is triggered by the rise of voltage on Channel 1. Channel 2 shows the condition of the normally-open relay contacts: when Channel 2 is 0 V, the contacts are open, when it is +5 V, the contacts are closed. The quench diode across the coil prevents generation of a rather large voltage (due to Lenz's law) and arcing of the SPST switch contacts when the switch is opened.

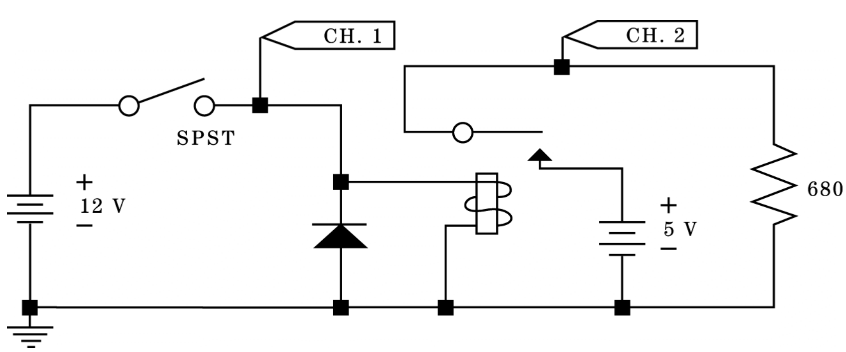


Figure 1

Measuring the time required for the relay contacts to open once the SPST switch is opened requires only that the triggering on Channel 1 be changed to negative slope.

Procedure A - Observing And Measuring Contact Closure Delay Time:

1) Refer to the information in Figure 2 for oscilloscope control settings, and adjust your oscilloscope accordingly.

2) Set the supply voltage to 12 V, and open the SPST switch. Press the **RUN** hardkey. Now close the switch. The sweep of the oscilloscope should be triggered once, and a new trace recorded (see Figure 2 for a typical display). You will have to press the **Run** hardkey after each trigger to "arm" the sweep again.

3) Press the **Stop** hardkey, then press the **Display** hardkey followed by the **Vectors On** softkey. Vectors On essentially "connects the dots", giving a better display of the trace for Channel 2. Notable are the delay time between the application of the coil voltage and contact closure, and the many bounces of the contacts (lasting about 1ms) prior to their closing for good. In Figure 2, the contact closure delay is about 7.64 ms. Record the contact closure delay time in the table below.

4) Change the supply voltage to 15 V, and then to 9 V, and repeat the measurement of delay time. Record results in the table. See Figures 3 and 4 for typical displays.

Supply Voltage (V)	Contact Closure Delay Time (ms)
9	
12	
15	

Procedure B - Observing And Measuring Contact Opening Delay Time:

1) Keep the circuit and the probe locations as they were in procedure A. Return the supply voltage to 12 V. Change the oscilloscope settings as indicated in Figure 5.

2) See Figure 5. Measure the time between opening of the SPST switch and the opening of the relay contacts, and record results in the table below. Notice the coil voltage dropping rather cleanly from 12 V to 0 V.

3) Now, remove the quench diode, change the oscilloscope settings as indicated in Figure 6 (note the Ch. 1 V/Div!), and record the coil voltage and the load resistor voltage. A whole lot of shakin' is goin' on right after the switch opens! In Figure 6, the voltage on Ch. 1 is over 300 Vpp. Also notable is the contact bouncing, which did not occur when the quench diode was present.

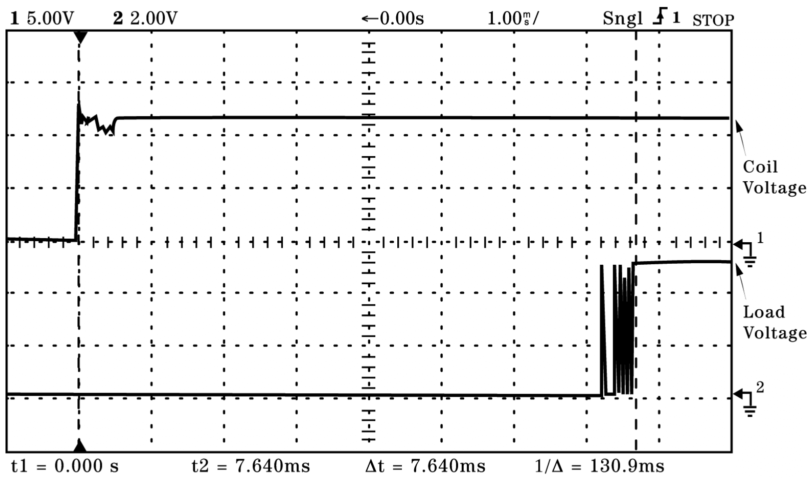
CAUTION for Lab Manager: maximum voltage on scope is 400 V before damage. Be sure of values.

Quench Diode	Contact Opening Delay Time (ms)
In place across relay coil	
Removed from relay coil	

4) In Figure 7, the time immediately after the switch opens is recorded. For about 200 ms, arcing occurs across the SPST switch contacts, resulting in high frequency oscillations with nearly 300 Vpp amplitude.

5) Based on the above observations and data, can you explain why most electronic circuits involving relays with DC coils do use quench diodes?

6) Why does the quench diode increase the contact opening delay time? What happens to the relay coil current at and after the time the SPST switch opens, with the diode present? with the diode absent?



	State	Volts/Div	Position	Couplg	BW Lim	Invert	Probe
Chan 1	On	5.000 V	156.3m V	DC	Off	Off	10:1
Chan 2	On	2.000 V	-5.937 V	DC	Off	Off	10:1
Chan 3	Off	100.0mV	0.000 V	DC	---	---	1:1
Chan 4	Off	100.0mV	0.000 V	DC	---	---	1:1

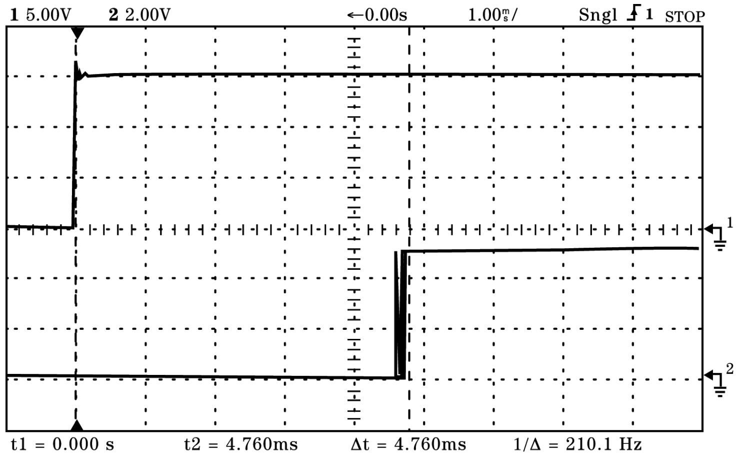
	Mode	Main Time/Div	Main Delay	Time Ref	Delayed Time/Div	Delayed Delay
Horizontal	Normal	1.000ms/	0.000 s	Left	-------------	-------------

Trigger	Mode	Source	Level	Holdoff	Slope	Couplg	Reject	NoiseRej
	Single	Ch 1	3.125 V	200.0ns	Pos	DC	Off	Off

Display Mode: Normal

Cursors: t1=0.000 s t2=7.640ms V1(1)=0.000 V V2(1)=0.000 V

Figure 2- 12 VDC Relay Contact Closure Delay Time, Supply Voltage = 12 VDC



	State	Volts/Div	Position	Couplg	BW Lim	Invert	Probe
Chan 1	On	5.000 V	156.3m V	DC	Off	Off	10:1
Chan 2	On	2.000 V	-5.937 V	DC	Off	Off	10:1
Chan 3	Off	100.0mV	0.000 V	DC	---	---	1:1
Chan 4	Off	100.0mV	0.000 V	DC	---	---	1:1

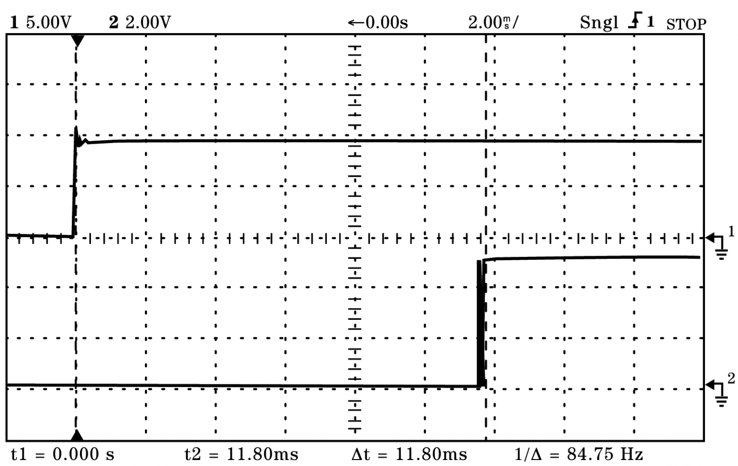
	Mode	Main Time/Div	Main Delay	Time Ref	Delayed Time/Div	Delayed Delay
Horizontal	Normal	1.000ms/	0.000 s	Left	-------------	-------------

Trigger	Mode	Source	Level	Holdoff	Slope	Couplg	Reject	NoiseRej
	Single	Ch 1	3.125 V	200.0ns	Pos	DC	Off	Off

Display Mode: Normal

Cursors: t1=0.000 s t2=4.760ms V1(1)=0.000 V V2(1)=0.000 V

Figure 3 – 12 VDC Relay Contact Closure Delay Time, Supply Voltage = 15 VDC



	State	Volts/Div	Position	Couplg	BW Lim	Invert	Probe
Chan 1	On	5.000 V	156.3m V	DC	Off	Off	10:1
Chan 2	On	2.000 V	-5.937 V	DC	Off	Off	10:1
Chan 3	Off	100.0mV	0.000 V	DC	---	---	1:1
Chan 4	Off	100.0mV	0.000 V	DC	---	---	1:1

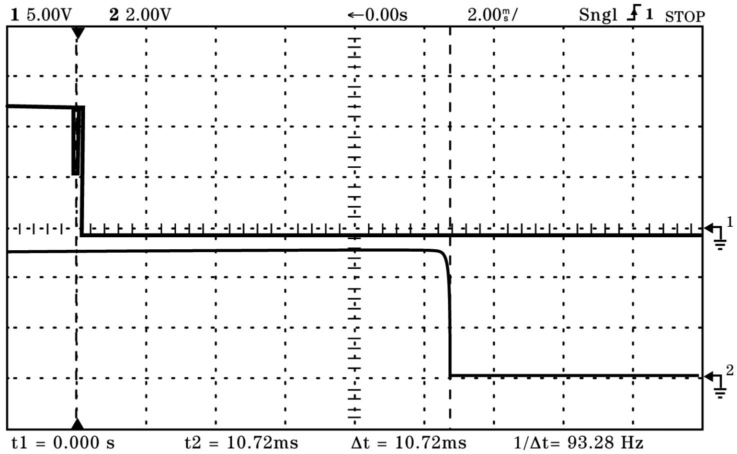
	Mode	Main Time/Div	Main Delay	Time Ref	Delayed Time/Div	Delayed Delay
Horizontal	Normal	2.000ms/	0.000 s	Left	-------------	-------------

Trigger	Mode	Source	Level	Holdoff	Slope	Couplg	Reject	NoiseRej
	Single	Ch 1	3.125 V	200.0ns	Pos	DC	Off	Off

Display Mode: Normal

Cursors: t1=0.000 s t2=11.80ms V1(1)=0.000 V V2(1)=0.000 V

Figure 4 – 12 VDC Relay Contact Closure Delay Time, Supply Voltage = 9 VDC



	State	Volts/Div	Position	Couplg	BW Lim	Invert	Probe
Chan 1	On	5.000 V	0.000 V	DC	Off	Off	10:1
Chan 2	On	2.000 V	-5.937 V	DC	Off	Off	10:1
Chan 3	Off	100.0mV	0.000 V	DC	---	---	1:1
Chan 4	Off	100.0mV	0.000 V	DC	---	---	1:1

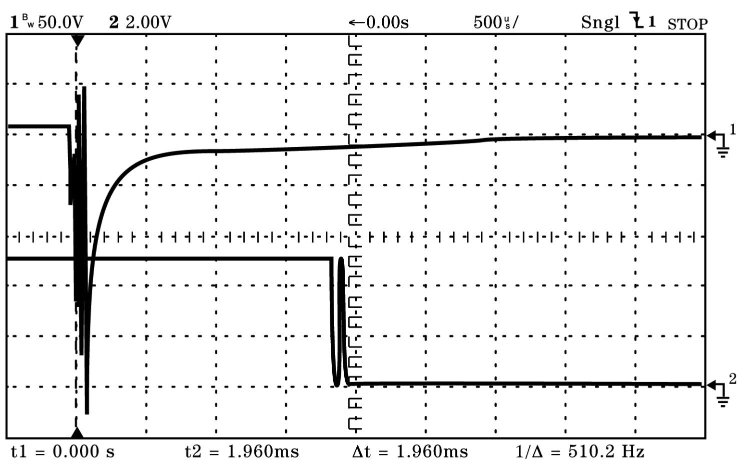
	Mode	Main Time/Div	Main Delay	Time Ref	Delayed Time/Div	Delayed Delay
Horizontal	Normal	2.000ms/	0.000 s	Left	-------------	-------------

Trigger	Mode	Source	Level	Holdoff	Slope	Couplg	Reject	NoiseRej
	Single	Ch 1	7.187 V	200.0ns	Neg	DC	Off	Off

Display Mode: Normal

Cursors: t1=0.000 s t2=10.72ms V1(1)=0.000 V V2(1)=0.000 V

Figure 5 – 12 VDC Relay Contact Opening Delay Time, Quench Diode Present Across Relay Coil



	State	Volts/Div	Position	Couplg	BW Lim	Invert	Probe
Chan 1	On	50.00 V	100.0 V	DC	On	Off	10:1
Chan 2	On	2.000 V	-5.937 V	DC	Off	Off	10:1
Chan 3	Off	100.0mV	0.000 V	DC	---	---	1:1
Chan 4	Off	100.0mV	0.000 V	DC	---	---	1:1

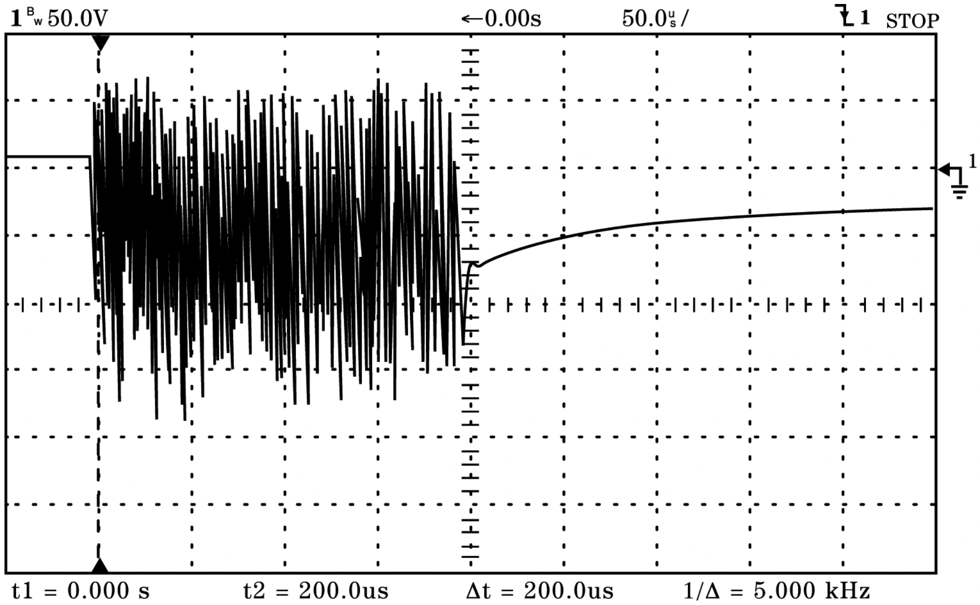
	Mode	Main Time/Div	Main Delay	Time Ref	Delayed Time/Div	Delayed Delay
Horizontal	Normal	500.0us/	0.000 s	Left	-------------	-------------

Trigger	Mode	Source	Level	Holdoff	Slope	Couplg	Reject	NoiseRej
	Single	Ch 1	-148.4 V	200.0ns	Neg	DC	Off	Off

Display Mode: Normal

Cursors: t1=0.000 s t2=1.960ms V1(1)=0.000 V V2(1)=0.000 V

Figure 6 – 12 VDC Relay Contact Opening Delay Time, Quench Diode Absent Across Relay Coil



	State	Volts/Div	Position	Couplg	BW Lim	Invert	Probe
Chan 1	On	50.00 V	100.0 V	DC	On	Off	10:1
Chan 2	Off	2.000 V	-5.937 V	DC	Off	Off	10:1
Chan 3	Off	100.0mV	0.000 V	DC	---	---	1:1
Chan 4	Off	100.0mV	0.000 V	DC	---	---	1:1

	Mode	Main Time/Div	Main Delay	Time Ref	Delayed Time/Div	Delayed Delay
Horizontal	Normal	50.00us/	0.000 s	Left	-------------	-------------

Trigger	Mode	Source	Level	Holdoff	Slope	Couplg	Reject	NoiseRej
	Single	Ch 1	-181.3 V	200.0ns	Neg	DC	Off	Off

Display Mode: Normal

Cursors: t1=0.000 s t2=200.0us V1(1)=0.000 V V2(1)=0.000 V

Figure 7 – Coil Voltage of 12 VDC Relay Being Turned Off, Quench Diode Absent Across Relay Coil