DATE: 7-2-14
FILE NAME: TRANDRV.DWG
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RELAY OPERATION

DC Relays are simple devices. If you apply the correct voltage level across the relay coil it will activate the relay and force the high current contacts to close or open - depending on the relay and the way you hook up the circuit. Fig. 1 shows a Single Pole Double Throw (SPDT) relay. Switch S1controls (On or Off) the relay circuit.

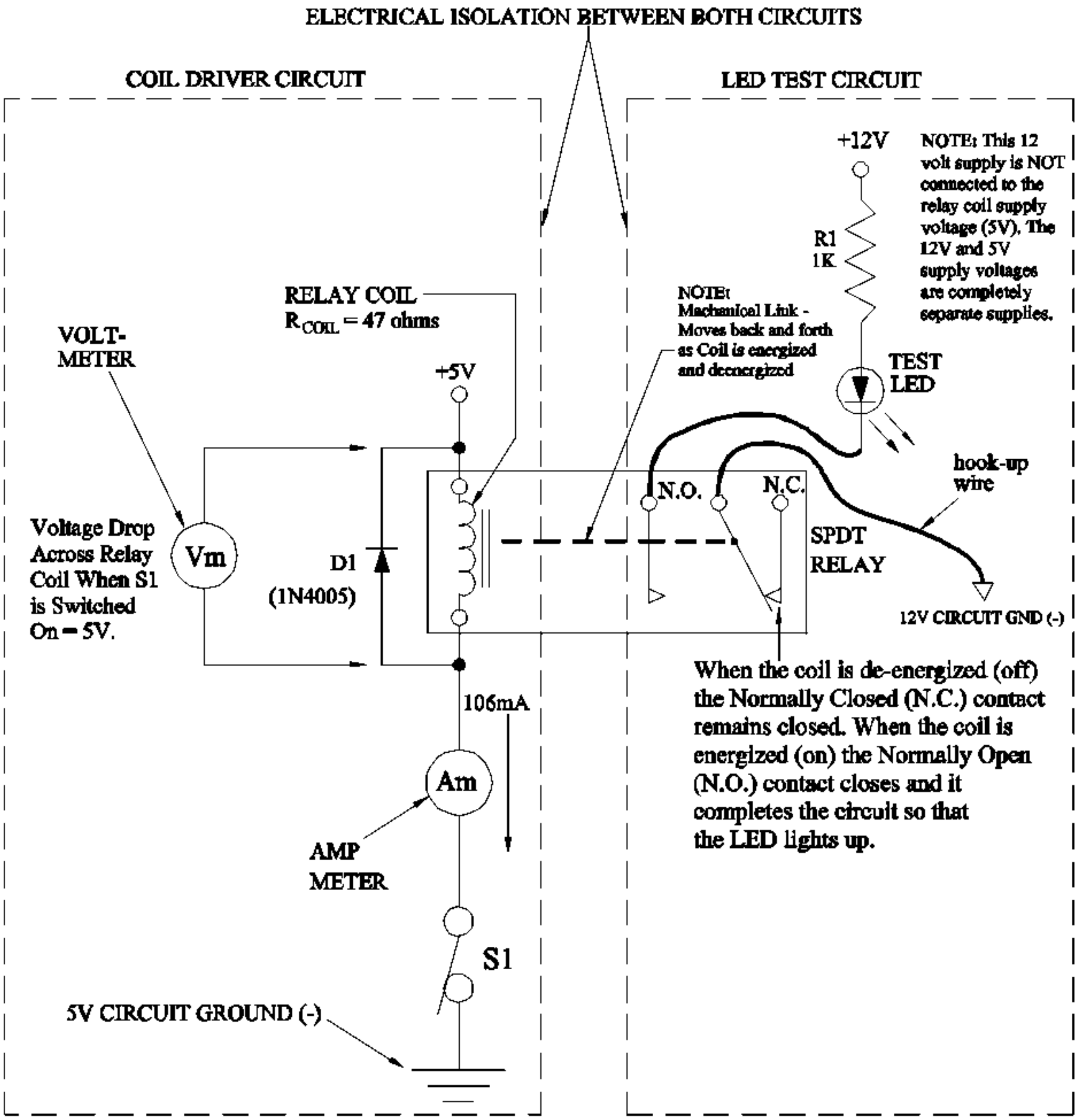

Fig. 1

Obviously, if you close switch S1 in Fig. 1 the circuit is complete, the relay coil is energized, the N.O. contacts close, and the LED turns On. Using Ohm's Law to calculate the current through the coil we get:

$$Icoil = \frac{Vcc}{Rcoil}$$

$$Icoil = \frac{5V}{47\ ohm}$$

Icoil = 106mA (current through the relay coil when Switch S1 is closed)

As you can see, the relay coil will receive 106mA when the switch S1 is closed. If you were to look up a relay like the Fujitsu SPDT FTR-H1 you'd see a specification called "Rated Coil Voltage' or just 'Rated Voltage'. This is the voltage at which the relay will reliably energize the coil. In this case, that voltage is 5 volts.

TRANSISTOR RELAY CONTROL:

The circuit in Fig. 1 works fine if all you need is a machanical switch (S1) to control a relay, but if you intend to connect a relay to a microcontroller you'll need another kind of switch. What you need is an electronic device that acts like a switch, doesn't use a lot of current, and can be easily controlled by a microcontroller. You guessed it - a Transistor.
There are several steps to designing a transistor controlled relay circuit. First, select the appropriate relay for your application. If you relay is going to switch a motor on and off, then the relay contacts actually connected to the motor must be able to handle the maximum current the motor will draw from the motor's power supply. It should be noted here that motors, when first turned on, can draw 2 to 10 times the current compared to normal operation. This is called "Inrush Current". Make sure you select relay contacts that can handle this type of current. In the relay catalog, under Contact Data, you'll find the 'Maximum Operating Current' or 'Maximum Switching Current' listed.

After selecting the correct high current contact rating for your DC relay, you should look under 'Coil Data' and 'Coil Rating' specifications and mark down the following parameters on a piece of paper: 'Rated Voltage' (or Coil Rated Voltage) and 'Coil Resistance'. It's very important that you select a DC relay with a High Coil Resistance. Why? Well, the higher the relay coil resistance, the lower the current required to energize the coil. For example, if we have a 5V relay with a coil resistance of 50 ohms, the current requdred to energize the coil equals 100mA (5V / 50 ohms). Now, take a 5V relay with a coil resistance of 62 ohms and the current required to energize the coil is lowered to 80mA. Therefore, the higher the relay coil resistance the lower the current consumption.
Ok, now for an example circuit to show you how to calculate the correct electrical values for your transistor/relay circuit. In this example we'll use the following catalog data based on the FUJITSU, SPDT, FTR-H1, DC relay:

1. Coil Rated Voltage = 5V DC
2. Coil Resistance = 47 ohms

Since we're using a transistor as a simple SPST switch in this example, there will be a small voltage drop across the collector/emitter terminals when the transistor is turned on. Why? Well, once the transistor is completely turned on (saturation) it doesn't actually turn on all the way like a mechanical switch. Because of a small internal resistance (PN junctions) it will drop anywhere between .1V to .3V depending on the type of transistor.This voltage is usually specified as Vce(sat) on the transistor datasheet. Therefore, when we do the calculation for the correct coil current we have to include this voltage drop across the transistor. Now, the current required to energize the coil can be easily found by the following Ohm's Law formula:

$$I(coil) = \frac{Vcc - Vce(sat)}{R(coil)}$$

Vcc - Vce(sat) → Voltage Supply - Voltage across collector/emitter during saturation

R(coil) → Coil Resistance in ohms (R)

$$I(coil) = \frac{5V - .1V}{47 \text{ ohms}}$$

I(coil) = 104mA This is the current needed to activate the relay coil.

Notice in the example above the relay's coil resistance is 47 ohms. To see how important it is to select a DC relay with a high coil resistance, try subsituting 62 ohms for Rcoil in the above formula.The current difference is 104mA - 80mA = 24mA. If you're using a battery to power your relay circuit, saving 24mA could mean a longer battery life.

Now, we need a transistor that can supply 104mA of current to the coil in order to active the relay. Since the 2N2222A transistor can withstand a maximum of 800mA of current, we'll use it for our circuit. Fig. 2 shows one example of a transistor/relay coil circuit. Since we know the current required to energize the coil is 104mA, we can find the transistor's base current (Ib) by dividing 104mA (Ic(max)) by BETA(min). Normally BETA (*B*) is only a factor when you're working with transistor amplifiers. When using a transistor as a switch, gain (BETA) has no meaning or use because the transistor switch is only operating in two modes - "Saturation" mode and "Cutoff" mode. In other words, 'gain' is not a factor (not important) in transistor switches because the transistor is either fully on (saturation) or fully off (cutoff). In this example, we only use BETA(min) listed on the datasheet to get us to the "Edge of Saturation" (EOS). Now, to ensure that we put the transistor into a deep saturation, we add an Overdrive Factor" to the formula. The ODF is an arbitrary number between 2 and 10. See formula below:

$$Ib(EOS) = \frac{Ic(max)}{BETA(min)}$$

Ic(max) → collector current we need (104mA)

BETA(min) → minimum Beta listed on the datasheet

$$Ib(EOS) = \frac{.104}{100}$$

Ib(EOS) = 1mA

Note that this 1mA just puts us at the EOS. In order to ensure a deep saturation we apply an ODF of 10 to the 1mA. So now Ib becomes:

Ib = 1mA x ODF

Ib = 1mA x 10

Ib = 10mA

Ok, we have base current equal to 10mA. Now, in order to find the resistance value of the base resistor (Rb), we take the voltage coming into the base terminal of the transistor (Vin) and substract the base emitter junction voltage (Vbe) of .7 volts . The result is then divided by the transistor's base current (10mA). Therefore, the base resistor (Rb) value needed is 430 ohms. See formula below:

$$Rb = \frac{Vin - Vbe}{Ib}$$

Vin - Vbe → Voltage In at the base terminal - Voltage across Base/Emitter junction

Ib → Transistor's base current

$$Rb = \frac{5V - .7V}{.010}$$

$$Rb = 430 \text{ ohms}$$

Fig. 2 shows the correct transistor/relay circuit required to activate the relay.

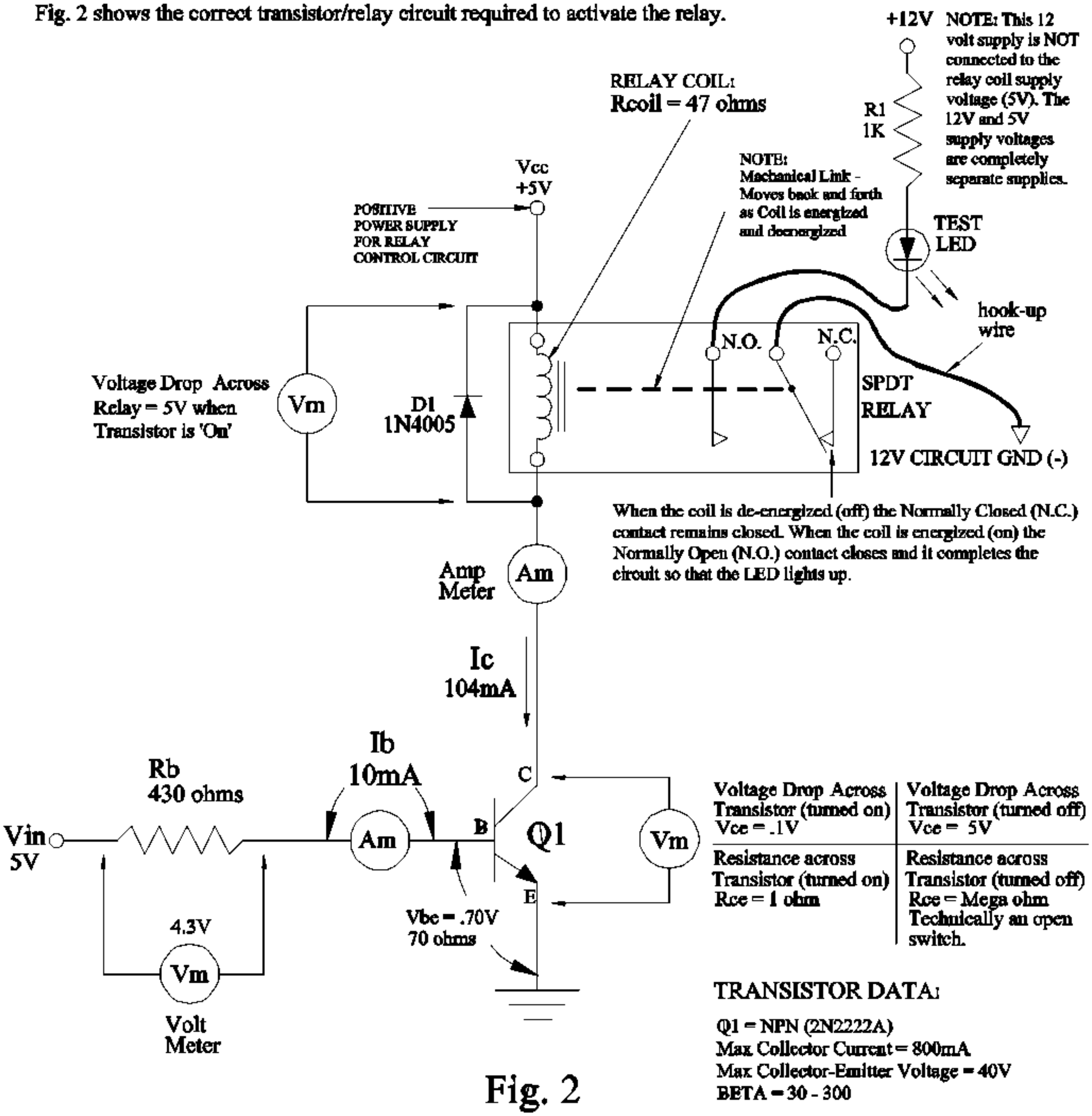

Fig. 2