Lesson 11

Title of the Experiment: Transistor switch connected to relay and control the external load
(Activity number of the GCE Advanced Level practical Guide - 24)

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Introduction:

The purpose of this experiment is to investigate and analyse electronic control systems. The systems use bipolar transistors. A range of input transducers are investigated and applied. The circuits should be able to control external output devices and component protection is considered.

Theory:

Relays involve the simple matter of switching. The difference between a switch that you turn on or off with your finger and a relay is the method of activation. You use your finger to turn a switch on or off, but a relay is activated electronically. The basic symbol of the relay is shown in Figure 1. The contacts are of three basic types, normally open (NO), normally closed (NC) and change- over (CO). In addition they can be either single pole (SP) or double – pole (DP).
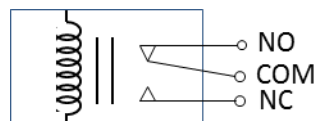
Figure 1: Circuit symbol for relay

COM= Common, it is the moving part of the switch.

NC= Normally Closed, COM is connected to this when the relay coil is off.

**NO**= Normally Open, COM is connected to this when the relay coil is on

The relay coil passes a relatively large current, typically 30-50 mA for a 6 V relay, but it can be as much as 100 mA for relays designed to operate from lower voltages. Most ICs (chips) cannot provide this current and a transistor is usually used to amplify small IC current to the larger value required for the relay coil.

Sometimes the DC current gain of the transistor is too low to directly switch the load current or voltage, so multiple switching transistors are used. Here, one small input transistor is used to switch "ON" or "OFF" a much larger current handling output transistor. To maximize the signal gain the two transistors are connected in a "Complementary Gain Compounding Configuration" or what is generally called a "**Darlington Configuration**" where the amplification factor is the product of the two individual transistors.

Darlington Transistors simply contain two individual bipolar NPN or PNP type transistors connected together so that the current gain of the first transistor is multiplied with that of the current gain of the second transistor to produce a device which acts like a single transistor with a very high current gain. The overall current gain Beta (β) or h_{fe} value of a Darlington device is the product of the two individual gains of the transistors and is given as:

$$\beta = \beta_1 X \beta_2$$

So Darlington Transistors with very high β values and high Collector currents are possible compared to a single transistor. An example of the basic types of Darlington transistor is given below.
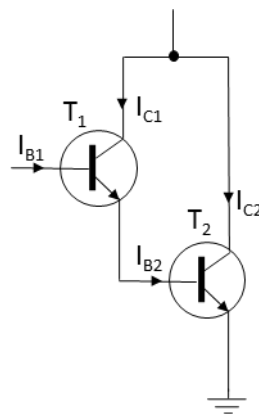
Figure 2: Darlington transistor configuration

The above NPN Darlington transistor configuration shows the Collectors of the two transistors connected together with the Emitter of the first transistor connected to the Base of the second transistor. Therefore the Emitter current of the first transistor becomes the Base current of the second transistor. The first or "input" transistor receives an input signal, amplifies it and uses it to drive the second or "output" transistor which amplifies it again resulting in a very high current gain. As well as its high increased current and voltage switching capabilities, another advantage of a Darlington transistor is in its high switching speeds making them ideal for use in Inverter circuits and DC motor or stepper motor control applications.

An important consideration when driving any inductive load is to provide a current path for the inductor, as the transistor turns off. This is accomplished in Figure 3 with diode D1. When the transistor is turned on, the inductance of the relay coil slows the rise in current. Being reverse-biased, the diode does not conduct. When the transistor turns off, the inductor voltage reverses polarity and becomes a source in order to maintain inductor current flow. If the diode were not present, Load voltage would increase to whatever voltage is necessary to maintain the current. This could be hundreds or thousands of volts! The transistor would not survive. With a suitable diode in place, the current can continue to circulate until the inductive energy is dissipated.
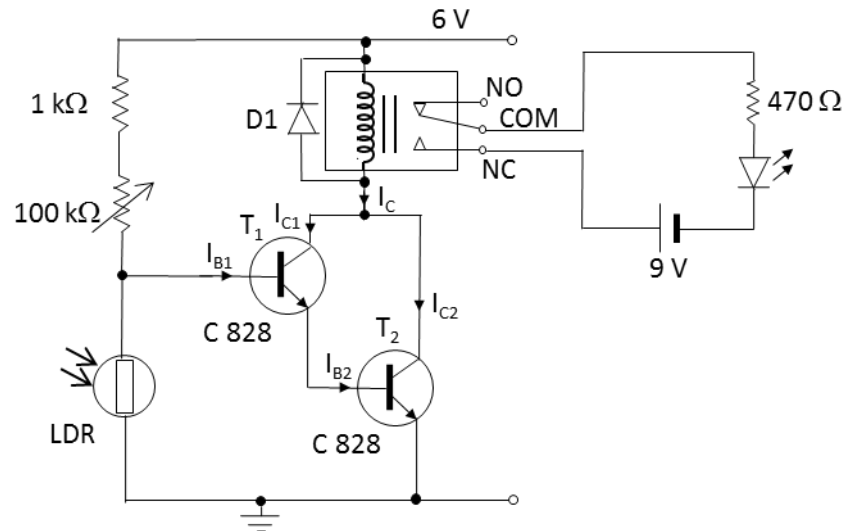
Figure 3: Transistor switch driving a DC relay

Learning outcomes:

When you have completed this experiment you will be able to:

- state and carry out calculations using the current gain.

- carry out calculations involving bipolar transistor switching circuits

- carry out calculations involving Darlington pair circuits

- design transistor circuits for a given purpose

- select suitable transistors, for connecting to signal sources and driving relays

Materials/Equipment:

Two C 828 transistor, Power supply (0-6 V), resistors (220 Ω, 1 kΩ), variable resistor (100 kΩ), 6 V SPST Relay, LDR, PTC, NTC, LED, Multimeters, Bread board, connecting wires.

Procedure:

i. Connect the circuit shown in the Figure3.

ii. Turn on the power supply and set the operating voltage to 6 V.

iii. Arrange the circuit so that the LDR is uniformly illuminated, e.g. having it point toward a ceiling light.

iv. The LDR's illumination should not be changed while setting the switching point.

v. Set the variable resistor (100 kΩ) so that the LED just stops shining.

vi. Cover the LDR and observe the LED. It should now shine.

vii. Measure and tabulate base current I_{B1} and I_{B2}, collector current I_{C1}, I_{C2} and I_C when the LDR is illuminated and when it is not.

Readings/Observations:

LDR	I_{B1} (µA)	I_{B2} (mA)	I_{C1} (mA)	I_{C2} (mA)	I_C (mA)	LED
Under Dark						
Under Light						

Note

You can repeat the experiment by using a thermistor instead of a LDR and follow the experimental procedure in lesson 10, part (IV) and (V).

Discussions:

Conclusions:

References:

Floyd, T. L. (2013). Electronic Devices (Conventional Current Version), 9th Edition, Prentice-Hall International.

Hambley, A. R., (2002). Electrical Engineering: Principles and Applications 3rd Edition, Prentice Hall

Horowitz, P. and Hill, W. (1997). The art of electronics, 2nd Edition, Cambridge University Press.

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