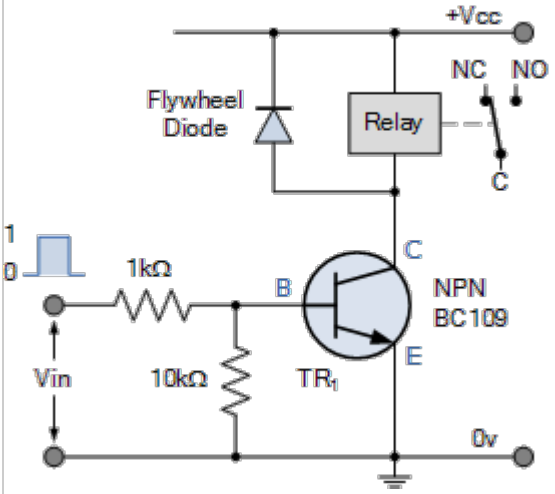


Relay Switch Circuit

Relays are electromechanical devices that use an electromagnet to operate a pair of movable contacts from an open position to a closed position.

The advantage of relays is that it takes a relatively small amount of power to operate the relay coil, but the relay itself can be used to control motors, heaters, lamps or AC circuits which themselves can draw a lot more electrical power.

The electro-mechanical relay is an output device (actuator) which come in a whole host of shapes, sizes and designs, and have many uses and applications in electronic circuits. But while electrical relays can be used to allow low power electronic or computer type circuits to switch relatively high currents or voltages both “ON” or “OFF”, some form of **relay switch circuit** is required to control it.

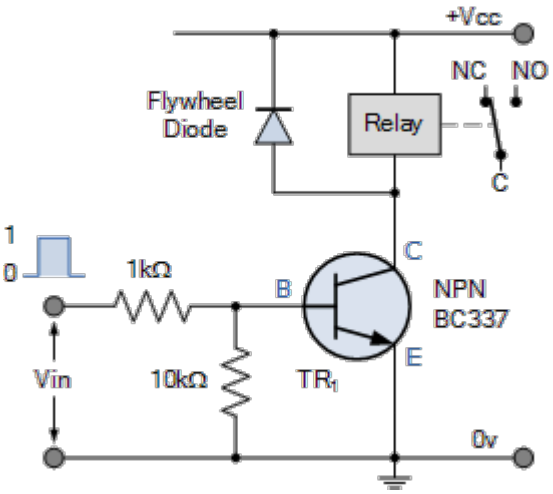
The design and types of relay switching circuits is huge, but many small electronic projects use transistors and MOSFETs as their main switching device as the transistor can provide fast DC switching (ON-OFF) control of the relay coil from a variety of input sources so here is a small collection of some of the more common ways of switching relays.

NPN Relay Switch Circuit

A typical relay switch circuit has the coil driven by a NPN transistor switch, TR1 as shown depending on the input voltage level. When the Base voltage of the transistor is zero (or negative), the transistor is cut-off and acts as an open switch. In this condition no Collector current flows and the relay coil is de-energised because being current devices, if no current flows into the Base, then no current will flow through the relay coil.

If a large enough positive current is now driven into the Base to saturate the NPN transistor, the current flowing from Base to Emitter (B to E) controls the larger relay coil current flowing

NPN Relay Switch Circuit



Note that the relay coil is not only an electromagnet but it is also an inductor. When power is applied to the coil due to the switching action of the transistor, a maximum current will flow as a result of the DC resistance of the coil as defined by Ohms Law, ($I = V/R$). Some of this electrical energy is stored within the relay coil's magnetic field.

When the transistor switches "OFF", the current flowing through the relay coil decreases and the magnetic field collapses. However the stored energy within the magnetic field has to go some where and a reverse voltage is developed across the coil as it tries to maintain the current in the relay coil. This action produces a high voltage spike across the relays coil that can damage the switching NPN transistor if allowed to build up.

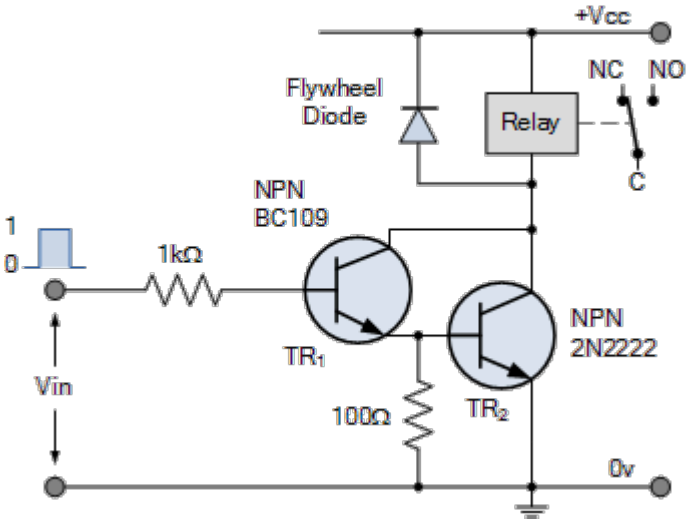
So in order to prevent damage to the semiconductor transistor, a "flywheel diode", also known as a freewheeling diode, is connected across the relay coil. This flywheel diode clamps the reverse voltage across the coil to about 0.7V dissipating the stored energy and protecting the switching transistor. Flywheel diodes are only applicable when the supply is a polarized DC voltage. An AC coil requires a different protection method, and for this an RC snubber circuit is used.

NPN Darlington Relay Switch Circuit

The previous NPN transistor relay switch circuit is ideal for switching small loads such as LED's and miniature relays. But sometimes it is required to switch larger relay coils or currents beyond the range of a BC109 general purpose transistor and this can be achieved using Darlington Transistors.

The sensitivity and current gain of a relay switch circuit can be greatly increased by using a Darlington pair of transistors in place of a single switching transistor. Darlington Transistor pairs can be made from two individually connected Bipolar Transistors as shown or available as one single device with standard: Base, Emitter and Collector connecting leads.

The two NPN transistors are connected as shown so that the Collector current of the first transistor TR1 becomes the Base current of the second transistor TR2. The application of a

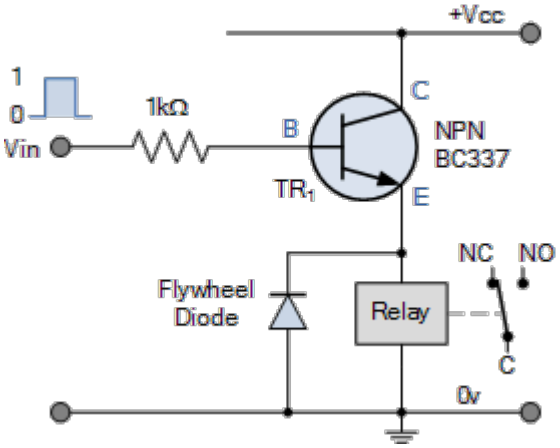


If two individual transistors are configured as a Darlington switching pair, then a small value resistor (100 to 1,000Ω's) is usually placed between the Base and Emitter of the main switching transistor, TR2 to ensure that it turns fully OFF. Again a flywheel diode is used to protect TR2 from the back emf generated when the relay coil is de-energised.

Emitter Follower Relay Switch Circuit

As well as the standard Common Emitter configuration for a relay switch circuit, the relay coil can also be connected to the Emitter terminal of the transistor to form an Emitter Follower circuit. The input signal is connected directly to the Base, while the output is taken from the Emitter load as shown.

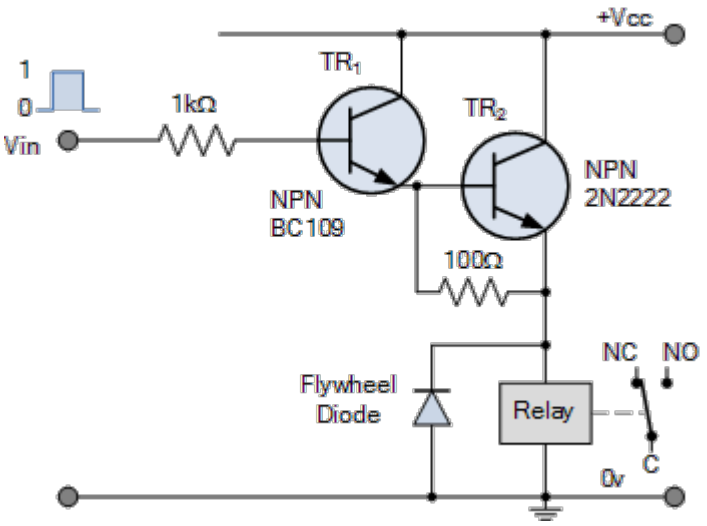
Emitter Follower Relay Switch Circuit



The Common Collector, or Emitter Follower configuration is very useful for impedance matching applications because of the very high input impedance, in the region of hundreds of thousands of Ohms while having a relatively low output impedance to switch the relays coil. As with the previous NPN relay switch circuit, switching occurs by applying a positive current to

TR2 due to the multiplication of the two Beta values.

Emitter Darlington Relay Switch Circuit

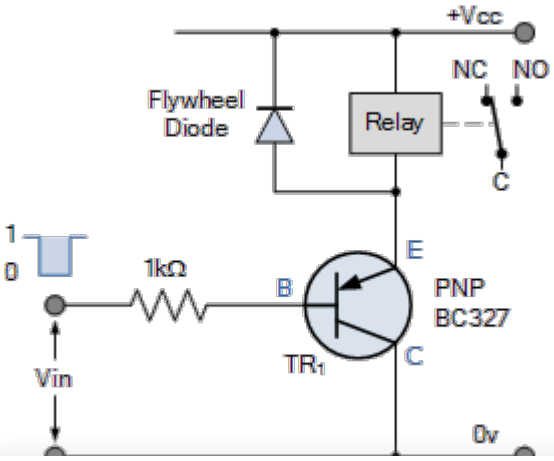


The Common Emitter Darlington relay switch circuit is useful to provide current gain and power gain with the voltage gain approximately equal to unity. Another important characteristic of this type of Emitter Follower circuit is that it has a high input impedance and a low output impedance, which make it ideal for impedance matching to large relay coils.

PNP Relay Switch Circuit

As well as switching relay coils and other such loads with NPN Bipolar Transistors, we can also switch them using PNP Bipolar Transistors. The PNP relay switch circuit is no different to the NPN relay switching circuit in terms of its ability to control the relays coil. However, it does require different polarities of operating voltages. For example, the Collector-Emitter voltage, Vce , must be negative for the PNP type to cause current flow from the Emitter to the Collector.

PNP Relay Switch Circuit



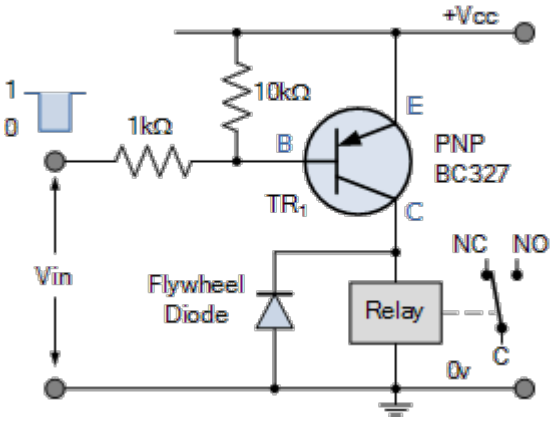
In other words, when Vin is HIGH the PNP transistor is switched “OFF” and so too is the relay coil. When Vin is LOW, the Base voltage is less than the Emitter voltage, (more negative) and the PNP transistor turns “ON”. The Base resistor value sets the Base current, which sets the Collector current that drives the relay coil.

PNP transistor switches can be used when the switching signal is the reverse for an NPN transistor, for example the output of a CMOS NAND gate or other such logic device. A CMOS logic output has the drive strength at logic 0 to sink sufficient current to turn the PNP transistor “ON”. Then current sinks can be turned into current sources by using PNP transistors and a power supply of opposite polarity.

PNP Collector Relay Switch Circuit

The operation of this circuit is the same as the previous relay switching circuit. In this relay switch circuit, the relay load has been connected to the PNP transistors Collector. The ON-OFF switching action of the transistor and coil occurs when Vin is LOW, transistor “ON” and when Vin is HIGH, transistor “OFF”.

PNP Collector Relay Switch Circuit



We have seen that either an NPN bipolar transistor or an PNP bipolar transistor can operate as a switch for relay switching, or any other load for that matter. But that there are two different conditions that need to be understood as the current flows in two different directions.

So in an NPN transistor, a HIGH voltage with respect to the Emitter is applied to the Base, current flows from the Collector to the Emitter and the NPN transistor switches “ON”. For a PNP transistor, a LOW voltage with respect to the Emitter is applied to the Base, current flows from the Emitter to the Collector and the PNP transistor switches “ON”.

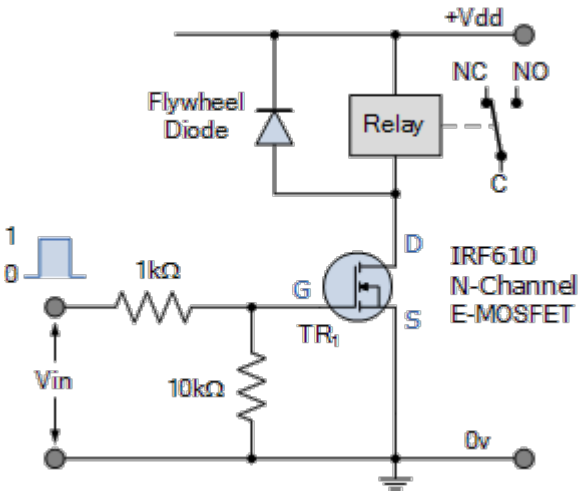
N-channel MOSFET Relay Switch Circuit

MOSFET relay switching operation is very similar to Bipolar Junction Transistor (BJT) switch operation seen above, and any of the previous circuits can be implemented using MOSFETs. However, there are some major differences in the operation of the MOSFET circuits with the

an Enhancement MOSFET, or E-MOSFET.

N-channel Enhancement MOSFETs (NMOS) are the most commonly used type of MOSFET as a positive voltage on the Gate terminal switches the MOSFET “ON” and zero or a negative voltage on the Gate switches it “OFF”, making ideal as MOSFET relay switch. Complementary P-channel Enhancement MOSFETs are also available which, like the PNP BJT work with opposite voltages.

N-channel MOSFET Relay Switch Circuit



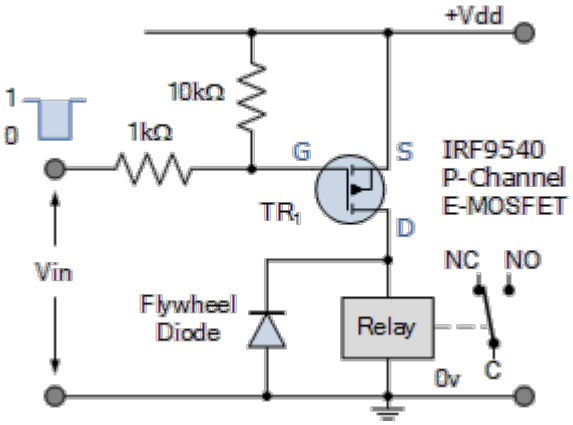
The above MOSFET relay switch circuit is connected in a common-source configuration. With zero voltage input, LOW condition, the value of V_{GS}, there is insufficient Gate drive to open the channel and the transistor is “OFF”. But when V_{GS} is increased above the MOSFETs lower threshold voltage V_T, the channel opens, current flows and the relay coil is operated.

Then the enhancement mode MOSFET operates as a normally open switch making it ideal for switching small loads such as relays. E-type MOSFETs have high “OFF” resistance but moderate “ON” resistance (OK for most applications), so when selecting one for a particular switching application, its R_{DS} value needs to be taken into consideration.

P-channel MOSFET Relay Switch Circuit

The P-channel Enhancement MOSFET (PMOS) is constructed the same as for the N-channel Enhancement MOSFET except that it operates with negative Gate voltages only. In other words, A P-channel MOSFET operates in the same fashion but with opposite polarities as the Gate must be more negative than the Source to turn “ON” the transistor by being forward-biased as shown.

P-channel MOSFET Relay Switch Circuit



In this configuration, the P-channels Source terminal is connected to +Vdd and the Drain terminal is connected to ground via the relays coil. When a HIGH voltage level is applied to the Gate, the P-channel MOSFET will be turned “OFF”. The turned “OFF” E-MOSFET will have a very high channel resistance and acts nearly like an open circuit.

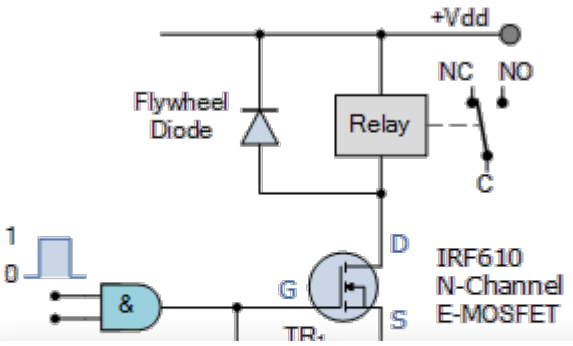
When a LOW voltage level is applied to the Gate, the P-channel MOSFET will be turned “ON”. This will cause current to flow through the low resistance path of e-MOSFETs channel operating the relay coil. Both N-channel and P-channel e-MOSFETs make excellent low voltage relay switching circuits and can easily be interfaced to a wide variety of digital logic gates and micro-processor applications.

Logic Controlled Relay Switch Circuit

The N-channel, enhancement-type MOSFET is extremely useful as a transistor switch because in its “OFF” state (with zero Gate bias) its channel has a very high resistance blocking current flow. However, a relatively small positive voltage greater than the threshold voltage V_T, on its high impedance Gate causes it to begin conducting current from its Drain terminal to its Source terminal.

Unlike the Bipolar Junction Transistor which requires a Base current to turn it “ON”, the e-MOSFET only requires a voltage on the Gate as due to its insulated Gate construction, zero current flows into the Gate. Then this makes the e-MOSFET, either N-channel or P-channel ideal to be driven directly by typical TTL or CMOS logic gates as shown.

Logic Controlled Relay Switch Circuit

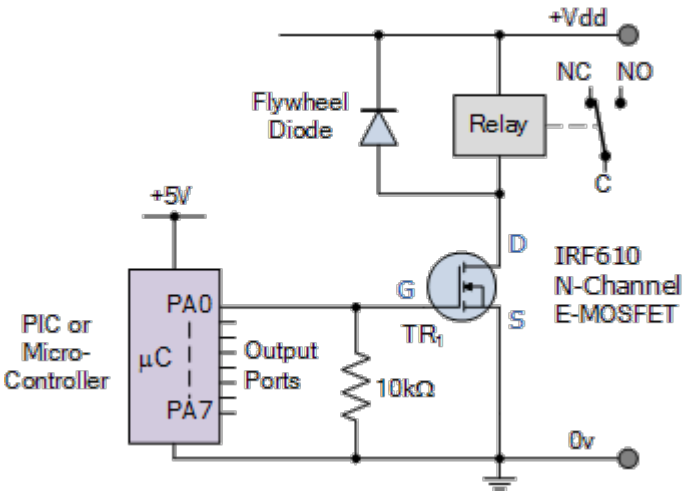


logic gates can only supply a limited amount of current, typically no more than about 20 mA. As e-MOSFETs are voltage operated devices and consume no Gate current, we can use a MOSFET relay switch circuit to control high power loads.

Micro-controller Relay Switch Circuit

As well as digital logic gates, we can also use the output pins and channels of micro-controllers, PIC's and processors to control the outside world. The circuit below shows how to interface a relay using a MOSFET switch.

Micro-controller Relay Switch Circuit



Relay Switching Circuit Summary

In this tutorial we have seen how we can use both Bipolar Junction Transistors, either NPN or PNP and Enhancement MOSFETs, either N-channel or P-channel as a transistor switching circuit.

Sometimes when building Electronic or Micro-controller circuits we want to use a transistor switch to control a high-power device, such as motors, lamps, heating elements or AC circuits. Generally these devices require larger currents or higher voltages than a single power transistor can handle then we can use a relay switching circuit to do this.

Bipolar transistors (BJT's) make very good and cheap relay switching circuits, but BJT's are current operated devices as they convert a small Base current into a larger load current to energise the relay coil.

However, the MOSFET switch is ideal as an electrical switch as it takes virtually no Gate current to turn "ON", converting a Gate voltage into a load current. Therefore, a MOSFET can be operated as a voltage-controlled switch.

In many applications bipolar transistors can be substituted with enhancement-type MOSFETs offering faster switching action, much higher input impedance, and probably less power dissipation. The combination of a very high Gate impedance, very low power consumption in its "OFF" state, and very fast switching capability makes the MOSFET suitable for many digital

spikes.

Also for additional protection of either BJT’s or MOSFETs, always use a flywheel diode across and relay coil to safely dissipate the back emf generated by the transistors switching action.

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113 Comments

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Submit

- *Mohammed Yasar*

  Not working with 3906, the aim is to make relay module with high control pin, because 2 pins in D1 mini are pulled High.

- *Emmanuel Gabriel*

  Please, can a relay be use for a big alternator which it’s current always dropped once a load is but on it?

  Posted on December 06th 2021 | 2:56 pm
  Reply
- *Prashant Shevate*

  Very useful for relay switching circuits with transistors and MOSFETs.

  Posted on June 04th 2021 | 5:15 pm
  Reply
- *Idowu Isaac*

  Hello Sir, I want to make an automatic light sensor using IR SENSOR with a 4017 counter. And bc547 in the circuit.. can I connect the lamp to an AC source without having any problem?

  Posted on June 02nd 2021 | 8:16 pm
  Reply
- *Nico*

  Hi

  Hope you can help

  I am trying to build a circuit (which I think should work with a transistor and a relay), its job will be as follows

  It must monitor 2 sets of batteries (A & B) , while A or B is in use, as soon as it (A or B)(the one in use) drops by 1.5v, the circuit must automatically change to battery B and or A and then also simeltaneously charge Either of the Depleted batteries to it’s full potential !

  I am using 4 Laptop batteries in two banks of 7.4 v each.

  This circuit must run a Motor (4-5v)

  Thanks in advance

  Posted on May 02nd 2021 | 3:43 am
  Reply
- *Sanjeet Kumar*

  what is realy

  Posted on April 09th 2021 | 11:56 am
  Reply
- *shahrokh*

  excellent

chamber through airlock bubblers on top. The air pump is on a timer. There are ceramic radiant heaters on top that are plugged into an electronic thermostat with an outlet that lets me set the high and low temps to turn the lamps on or off. I have a fogger submersed just below the surface of the water in a hole in the center of the styrofoam tray to help keep the air in the chamber humid. I want the fogger to run anytime either the air pump and/or heat lamps are on. How can I do this, do I need some sort of relay?

Posted on January 03rd 2021 | 2:55 pm
Reply

- *kalyan Kumar Chatterjee*

  CT operated relay triggiring block diagram with circuit for final triggring circuit.

  Posted on November 17th 2020 | 11:14 am
  Reply

- *clayton raj*

  Dear sir
  My requirements is 10 valves has to be operated in 10 different time in one by one. Not operated in at a time.

  Posted on November 05th 2020 | 5:37 am
  Reply

- *Sree*

  In the npn transistor relay circuit…can I give a 12 V ac supply using a step down transformer…..or we can only give dc input?

  Posted on October 21st 2020 | 7:07 am
  Reply

  - *Wayne Storr*

    Using an AC supply would cause the transistor and therefore the load relay to switch ON/OFF continually at a rate determined by the frequency of the supply. There would be no control.

    Posted on October 21st 2020 | 7:03 pm
    Reply

- *JiHoo*

  How does the darlington switch work actually?, if the first switching NPN transistors feeds current to second transistor and it starts to pull down the collector close to zero, what gives current to 1st transistor in this case?

  Posted on August 31st 2020 | 6:46 am
  Reply

- *Uttam Dutta*

  if I give 30 mili Volt to the base of first transistor , will the relay pick up. what should be the minimum Vin , in NPN Darlington Relay Switch Circuit

Posted on July 19th 2020 | 8:44 am
Reply

- *susanto*

  good explanation….I want to make car door lock mechanism, which triggered by certain speed, if reached…use hall effect voltage from speedometer…once closed, door still closed , even car speed reduced or stop….

  Posted on July 07th 2020 | 5:43 pm
  Reply
- *Simran Kaur*

  Using relay to make a circuit to Turn on and Off a Bulb using a switch. Relay coil voltage is 5V.
  Give answer please….

  Posted on June 13th 2020 | 2:43 pm
  Reply
- *feri*

  HI SIR. good circuits l need a circuit to control DC 12 volts motor speet with promrameble IC.
  thanks

  Posted on March 19th 2020 | 8:40 am
  Reply
- *Godwin*

  Location for TCM relay on Hyundai Elantra 2005

  Posted on February 25th 2020 | 7:50 pm
  Reply
- *sean c.*

  I AM GETTING ANGRY WITH MY COMPUTER NOT UNDERSTANDING WHAT A SNIFFER CIRCUIT IS THAT CONTROLS A RELAY. INSTEAD OF USING A FOOT PEDAL TO KEY AN RF AMP, YOU MAKE A SNIFFER CIRCUIT THAT DETECTS WITH A WIRE THE RF THAT IS COMING FROM THE RADIO OR TRANSMITTER. THIS IN TURN CLOSES THE RELAY FOR THE HIGH VOLTAGE ON TUBES OR TRANSISTORS. ANOTHER RELAY CAN BE ADDED REMEMBER EACH RELAY HAS IT’S OWN DIODE ACROSS THE RELAYS. THE OTHER RELAY CAN BE USED FOR SINGLE SIDE BAND WITH ELECTROLYTIC CAP, AND SWITCH. THANK YOU VERY MUCH FOR LISTENING.PLEASE SEND A SIMPLE SCHIMATIC OR WEB SIGHT !

  Posted on December 12th 2019 | 8:15 pm
  Reply

Close