EDUCATIONAL MODULES

For LEARNING and to PRACTISE the ELECTRONICS

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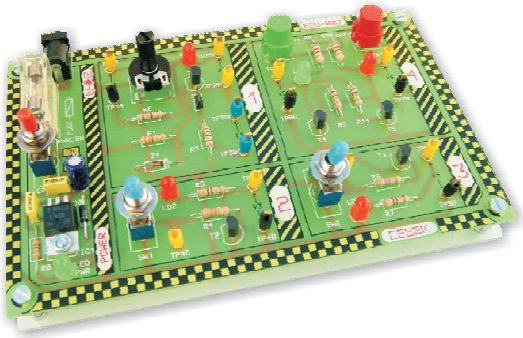
EDU-007. The NPN and PNP Bipolar transistors



The EDU-007 module describes and experiments with basic concepts of bipolar NPN and PNP transistors.
Different experiments of this module allow to show three transistor' operating areas: Active, Cut and saturation, requiring only a power supply and a multimeter to start these experiments.
The practice includes internal operating graphics regarding transistor's structure.

- **Practice 1**: The bipolar transistor Definition and operating mode.
- **Practice 2**: Transistor operating as current source.
- **Practice 3**: The switch NPN transistor.
- **Practice 4**: The switch PNP transistor.
- **Practice 5**: R.S Scale with transistors.

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Warranty and Do not forget.

Cebek educational modules included in the EDU serial offer several practices to analyse, experiment and to learn basic knowledge on the studied theme. Nevertheless, their function is not to make a mini-class on each theme, but to complete and to be used as basis, as well as to allow to experiment on the theoretical theme evocated by the teacher. For this reason, we suggest you to use modules form the EDU serial under the supervision and the direction of a teacher.

Cebek doesn't offer a consulting service as concern the theoretical or the operating principles concerning the theme deal with the module. It only offers a technical assistance regarding questions and problems coming from the circuit's internal operating mode.

All Cebek modules included in the EDU serial have a warranty of 3 years as concerning components and labour man. All damages provoked by external causes (from the circuit), as well as wrong connections or installations or due to an operating mode no indicated into the module's documentation won't be covered by the warranty. More over, all wrong or incorrect handling won't be excluded from the warranty. For any claim, you have to present the corresponding invoice.

To contact our technical department, you can send a message to sat@cebek.com, or a fax :Nº+34.93.432.29.95 or a mail to the following address: CEBEK, c/Quetzal, 17-21, 08014 Barcelona (SPAIN).

Rules and Identification of the EDU serial elements.

To make easier the identification and for a single rule as concern different practices and educational Cebek modules, all common elements will answer to colour code and to a shape.

Test Point. (TP).

It allows to connect oscilloscope's or multimeter extremities to read parameters relating to the practice. According to its colour, it will indicate that the Test Point (TP) is connected to the positive or to the negative of the circuit, as well as reads concerning current, voltage, load, etc….

TP. ⊕ circuit
Red

TP. ⊖ circuit
Black

TP. Tension
Yellow

TP. Courant
Blue

TP Without current or TP AC.
White

Conmutator / Switch.

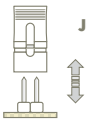
According to the colour of the switch, you can control the voltage, the current

Power supply
Red

Current
Blue

Voltage
Yellow

Logical
Green



Jumper.

It allows to close or open a signal or an electrical circuit

Important Point.

Very important point, reminder or part to memorize.

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Before to start...

Before to start a practice, it is very important to carefully read its instruction manual as well as corresponding indications.

You have to do correctly connections in indicated contact points, otherwise measures depending on these connections will be confuses or wrong.

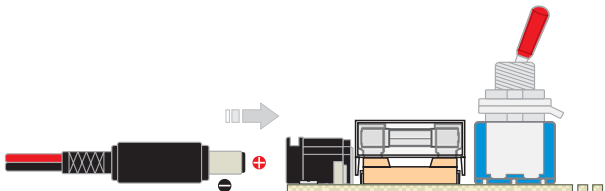
Do not make connections not indicated in the instruction manual to avoid to damage the circuit.
If the Led of the power supply "PWR" doesn't light on or if its function suddenly stops, you have to quickly disconnect the power supply for the device and check there is any short-circuit as well as the fuse's status.

Even if described practices can be done following instruction manual, we recommend you to use it under the supervision of a teacher who can advise and bring you a support (an help) concerning described concepts.

In the circuit, each practice will be delimited by a rectangle with the corresponding number. One or several experiment(s) can be reported and referenced to this practice.

Module's power supply.

The module has to be supplied at 12 V AC. You have to use a laboratory stabilised power supply like our Cebek FE-113.
The circuit's feed is done through the male connector inserted on the board, **do not inject signal on any other terminal placed on the circuit**. Once supplied, the circuit offers necessaries voltages to make experiments with each practice. To connect the power supply, the module includes a cable wit a male connector at one extremity and wires at the other extremity.
Connect all terminals to the transformer output. Finally, you could insert it into the module.
Note: The circuit fuse is 200 mA.



Material necesario.

You won't need any additional material or components to experiment with this module. You only need basis measure instruments to obtain and to compare obtained values from this practice.
For this module, you will need one or several multimeter with its function as voltmeter and ammeter. If you have an oscilloscope, you can also use it, substituting the voltmeter.

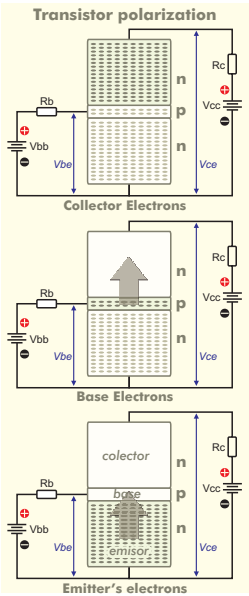
Bibliography.

- Electronics principles E. McGraw-Hill. Author: Albert Paul Malvino.
- with google: The bipolar transistor / BC547 / BC557

Practice 1: The bipolar transistor Definition and operating mode.

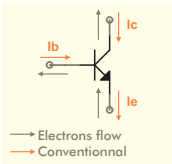
The module has been invented in 1951 by the physician William Schockley. Its analysis about minority carriers on the p-n union and the carriers function in the injection and the collection allowed the creation of the union transistor, composed by a p-n-p material sheet.
The new component, with a single small current at low impedance, was able to considerably increase the power at high impedance; opening therefore doors to the radio and television signals amplification. The transistor also can operates as a current switch, doing binaries operations. Later, integrating several transistors on a silicon fragment, the Integrated Circuit (IC) was born and with it, the beginning of the electronics and computer….

A transistor can be made of silicon or germanium. The most important difference between both is the value of the power barriers, 0,7V at 25°C in the first and 0,3 V in the second one. Even if its electrical operating mode is similar, the silicon transistor is the most popular and used in the industrial field.
The transistor is divided in three areas of "doping", the emitter, the base and the collector. When the configuration close a "p" area between two "n", the transistor is called npn and when it is the "n" area which is closed between two "p" areas, the transistor is called pnp.
The unions between doping areas are localized between emitter and base, and between base and collector.



When a voltage is applied between the base and the emitter, (Vbb), free electrons of the emitter are moved up to the base. Because this one is narrow and practically no doped, it allows that electrons have necessary time and life to move to the collector and to circulate through the Rc to the positive of the power supply Vcc, being a very low percentage (generally inferior to 1%) which will be lost in the base through Rb to the positive of the Vbb.

When the emitter operates like an electrons generator, it is defined Ie=Ib + Ic. Nevertheless, as the base current is so small regarding to the collector one, it is possible that Ic is practically equal to Ie. From the relation of three currents of the transistor, you can obtain parameters which determine the gain and each manufacturer will offer it in its technical characteristics. The Alfa of D.C is equal quotient resulting from Ic divided by Ie.
The Beta value in D.C for a transistor, will correspond to the value obtained by the division between Ic and Ib.



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Practice 2: Transistor operating as current source.

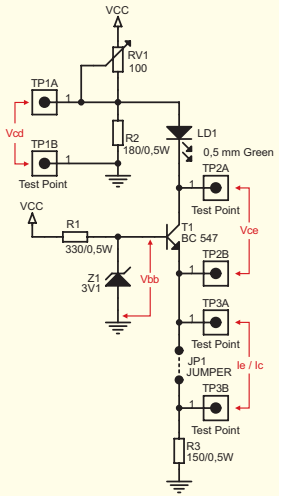
The Beta in continuous represents the current gain of a transistor, allowing to obtain through a small base current a higher collector current.
Applying following formulas, according the value of Ib or Ic, you can obtain with Beta, the transistor amplification.

$$Ib = \frac{Ic}{\beta_{dc}} \qquad Ic = \beta_{dc} \cdot Ib$$

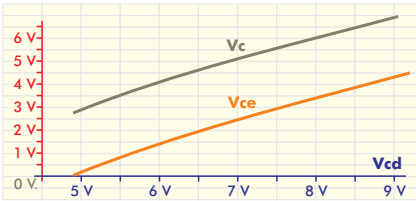
β_{dc}= Beta in continuous
Ib= Base Current Ic= Collector Current

The transistor can work in three operating areas; the active area, the cut area and the saturation area.
The practice 2 indicates an application for the transistor operating mode in the active area, through the polarization of the emitter.

The circuit operates like a constant current supply, adapting voltage changes from the power supply to always maintain a same emitter current. This application is specially appreciated and used in Leds supply circuits.
The potentiometer RV1 and R2 composes a voltage divisor allowing to adjust the voltage of the circuit used in the practice, (Vcd), between 4,5 and 8,5V approximately The led placed in serial have to change its luminosity according to the applied voltage, but the current will be maintained unchanged.
The constant power supply on the base, established at 3,1 V approximately, and the emitter resistance allow a constant current collector/emitter.
Applying a voltmeter between TP1A and TP1B point test and an other voltmeter between TP2A and TP2B, as well as an ammeter between TP3A and TP3B, and remove the jumper to allow the read in serial.
As it is indicated on the graphic, an increase of Vc is proportionally absorbed by Vce.



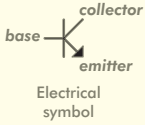
Electrical Drawing of the Practice 2



Ve= Vbb - 0,7
Vc = Vcd - Ic . Rc
Vce= Vc - Ve

Practice 3: The switch NPN transistor.

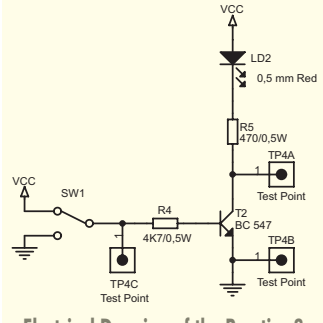
Resides of the operating in active area, a transistor can also operate in cut and saturation areas, where its basic function is not to amplify a current but to work in commutation. .



The practice 3 uses a NPN BC547 transistor to configure a transistor operating in commutation or switch. The electrical symbol of the npn is represented as it is indicated in the picture, where it is also described the BC547 pins' configuration

The bipolar transistor's operating in commutation mode, is equivalent to an operating mode always in cut or in saturation, with a control voltage and an output voltage.

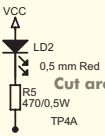
The bipolar transistor's operating in commutation mode, is equivalent to an operating mode always in cut or in saturation, with a control voltage and an output voltage.
You have to use two voltmeters, between point test TP4C and TP4B to monitor the control voltage of the circuit and between TP4A and TP4B to read the output voltage.
The SW1 switch assume the control voltage. It will apply to the base of the transistor, polarized through R4, the value of Vcc or the ground one.
When TP4C is connected to the round, the transistor will be localized in the cut area, and the collector/emitter voltage will equal to the maximum one offered by the circuit. If Vcc = 8,2V approx., Vce = Vcc – Vled. The transistor in cut is equivalent to an open circuit and therefore, the circuit of the led can be connected to the ground and then authorise the illumination. When you will commute SW1 and you will inject Vcc in TP4C, the transistor goes to the saturation area and it will operate like a short-circuit, or a closed switch, allowing that the circuit of the led closes to the ground and then it will light on.
To guarantee a correct operating mode of the transistor in the saturation area, it is recommended to reach the hard saturation, allowing the transistor to always operate in this area.

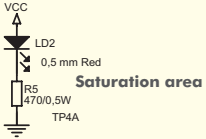


Electrical Drawing of the Practice 3

In the practice, there is a rule which guarantee the "hard" saturation of a transistor. It consists in using a base resistor, 10 times superior than the collector resistor.

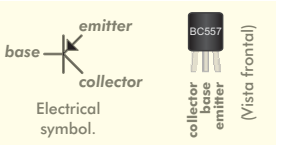
Equivalent Circuit of the transistor in the practice :





Practice 4: The switch PNP transistor.

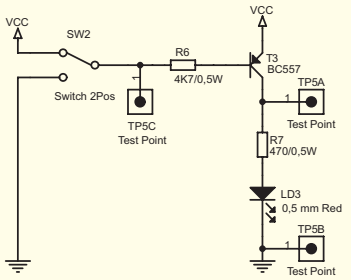
The transistor's operating in commutation mode is not restricted, logically, only to the NPN, the polarization of the base is also used in the same mode for PNP transistors.



The equivalent to the BC547 NPN in PNP configuration is the BC557, this on maintains the same pin configuration and its technical characteristics are basically identical. The electrical symbol of the PNP is different of the NPN, as it is indicated in

A PNP transistor installs doped areas in opposite mode than a NPN, for this reason it has an inverted operating mode.
If in the practice 3, the circuit was commuted to the ground through the emitter and the load was commuted to the positive. With the PNP transistor, it is the opposite; the circuit will be commuted to the positive and the load to the negative.

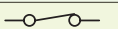
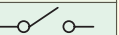
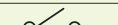
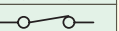
Connect a voltmeter between point test TP5C and TP5B to monitor the control voltage of the circuit and connect an other voltmeter between TP5A and TP5B for the exit circuit.
More over, the control voltage is injected through a switch, in this case SW2, on the R6 base resistor. Nevertheless, in this occasion, when TP5C is connected to Vcc, the transistor (T3), will operate in the cut area and will act as an open switch, impeding the led feed.
When the TP5C is connected to the ground, T3 will remain saturated and it operates like a closed switch; therefore Vce will be equal to the maximum allowed by the circuit, (Vcc Vled), and the led will light on.



Electrical Drawing of the Practice 4

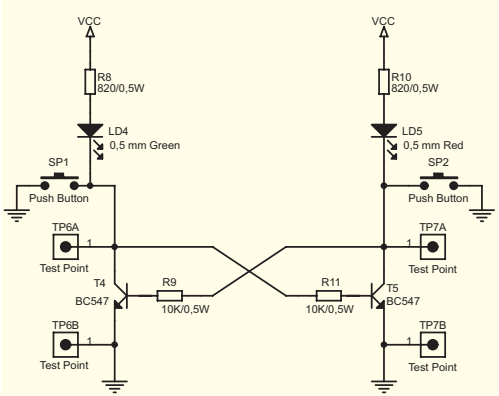
Observing both transistors' operating, npn and pnp in commutation mode, you can determinate that both operate like an inverter door. For a npn transistor, a positive voltage offers negative to the load and for a pnp one, the negative supplies a positive voltage to the load. Then, independently of the control signal type (positive or negative), you can control the activation/deactivation of a second signal using the corresponding transistor.

Transistor operating in commutation mode.

Control Signal	Output Circuit	
⊕		
0 V.		
	npn	pnp

Practice 5: R.S Scale with transistors.

The practice 5 will take profit of the transistor's operating in commutation mode to make a stable multivibrator. Its main application is to obtain two logical states in each output: logical zero o one, opposite between them.
All digital information is codified according to the same mode, logical zeros and ones, known as binary code. For several applications it is necessary, in addition to the signal itself and according to its changes, that it remains reflected with an opposite result, expressed as a "hopeless" signal.



Electrical Drawing of the Practice 5

To show the operating mode of this practice, you have to monitor Vce voltages of each transistor. To do that, you have to connect a voltmeter between TP6A and TP6B, and an other voltmeter between point test TP7.
The exercise consists of designate each push button according to the operating mode of the scale, R or S.

It is designated as RS scale because a control signal place the output of the main transistor or "Q" at high level, designated S (set). The other R signal (Reste), when it is activated it place the output of the main transistor at low level. The other transistor always operates in opposite (inverse) mode regarding to the main, which its output is designated as Q ("Hopeless Q").

When you press the green push button, you move to the ground the T5's base throughR11. The transistor is placed in cut and Vce = Vcc Vled.
The T5's Vce voltage, through R9, move the T4 transistor to saturation area, which operating as a short-circuit allows the green led to light on and also to maintain T5 in cut state.
When you press the red push button, this process will be repeated interchanging the cut and saturation states of the transistors and allowing the red led to light on.
Therefore, when a led is lighted on, the corresponding output will be in low level and when it is lighted off it will indicate an output at high level.