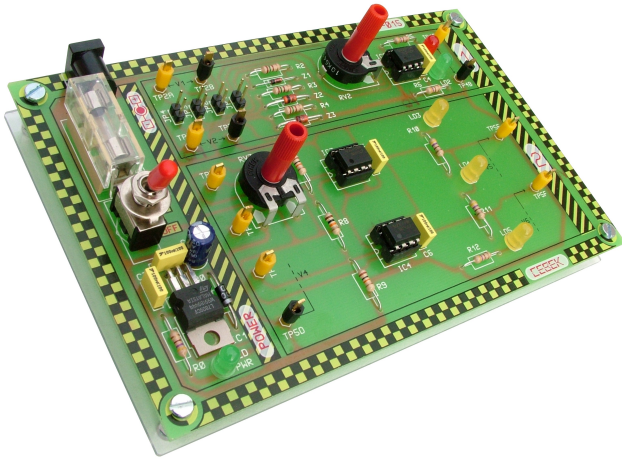




# cebek<sup>®</sup>



## THE 741 COMPARATOR EDU-015

The EDU-015 analyzes the 741 as comparator, a configuration and basic functionality in the use of operational amplifier in non linear circuits.

The EDU-015 offers an initial approach to the 741 and operational ones, offset compensation, inverter comparator, comparator with switching point in zero, or different from zero, inverter comparator or the window comparator, using different practices to contrast and to facilitate the understanding of the comparator operating mode.

Practice 0 - Introduction to the operational amplifier and the 741. Operational amplifier structure of and operating mode. The 741 operational, offset compensation, operational parameters.

Practice 1 - Circuits types with operational. Operational and the comparison, Comparator with switching point in zero. The crossing detector by zero.

Practice 2 - Comparator with switching point different from zero. Comparator fed with a single power supply and different reference voltages.

Practice 3 - Window comparator. Threshold answer and configuration to establish three switching points.

### 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.

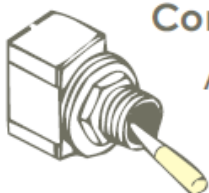
#### Test Point. (TP).

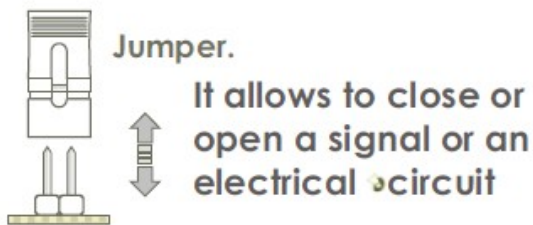
It allows to connect oscilloscope's or multimeter extremities to read parameters relating to the practice. According to its colour, it will indicate that the Test Point (TP) is connected to the positive or to the negative of the circuit, as well as reads concerning current, voltage, load, etc....



#### Commutator / Switch.

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





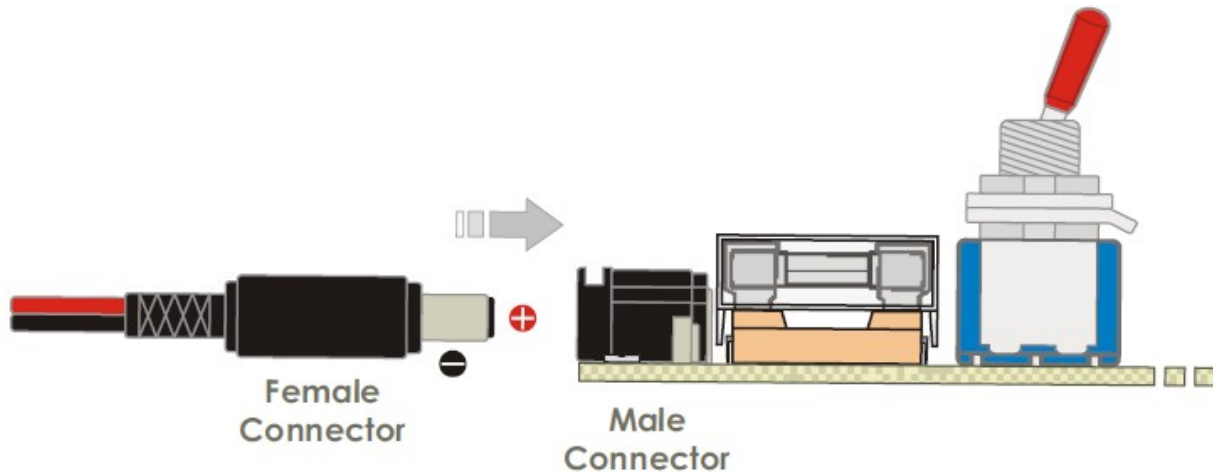
**Important Point.**  
Point with special importance,  
To remember.

### Module's power supply

The module is supplied at 12 V DC. You have to use a laboratory stabilised power supply like our Cebek FE-113. The circuit's feeding 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 necessary voltages to make experiments with each practice. To connect the power supply, the module includes a cable with a male connector at one extremity and wires at the other extremity.

Respecting the connector polarity, you have to connect each terminal to the corresponding and respective terminal of the power supply. Then, you could insert it on the module.

Note: The circuit fuse is 250mA.



### Required Material

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 multimeters with their voltmeter, ammeter or ohmmeter functions. If you have an oscilloscope, you could also use it to substitute the voltmeter.

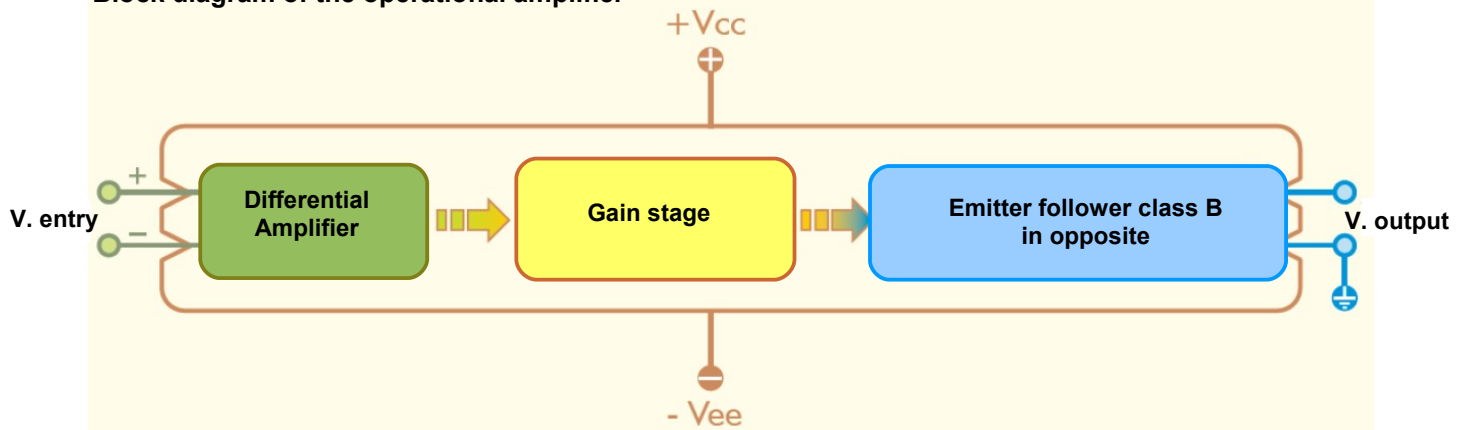
### Bibliography

- With Google: NE555
- With Google: Ne555 Fairchild
- Electronics Principles, (Mc Graw Hill)

### Operational amplifier introduction

The first operational amplifiers were made using discrete circuits for their use in analogical computers, their function was to do mathematical operations: sum, subtractions, multiplications, etc. Herein its terminology, (op amp). Actually op amp, or "operational", as they are usually denominated, are integrated into a IC, structured in a block with external terminals. The majority of operationals have a power limitation near to 1 watt, and although they exist some destined to high powers, most of the operational present in the market are well known for their specialization in the optimization of a determined characteristic, like the input offset current, the bandwidth, minimum noise, etc. This versatility, price and reliability have allowed to innumerable developments and applications, constituting one of the more basic active components in an analogical system. The internal structure of an op amp, although it is extremely complex, because it includes active loads, current mirrors, etc, can graphically indicated as a block composed by a differential amplifier, one additional win power stage and normally a B class emitter follower in counterphase, even if in some of them this last phase can be replaced by a differential output.

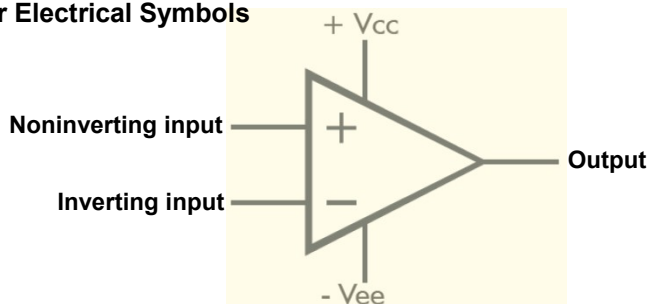
### Block diagram of the operational amplifier



The differential amplifier is composed by a current source that controls and provoke the differential amplifier polarization. The collector resistance is replaced by an active load, acting as a current source with a very high impedance which allows to obtain a considerably higher voltage gain. A final emitter follower, excited by the amplified signal increases the impedance level that allows to the EC a high voltage gain.

The B class emitter follower in counterphase collects the amplified signal. If the feeding is symmetrical, ideally the output voltage is equal to zero when the input voltage is also. The output value will always approach the maximum value of the symmetrical feed, positive or negative, according to the input polarization, decreasing between 1 and 2 V. because of the operational's internal voltage drop. If the input voltage is reversely polarized, the output is negative. If it is polarized without reverting it, the output is positive. Operational amplifier electrical symbol Inverter and no inverter input, (positive and negative polarization)

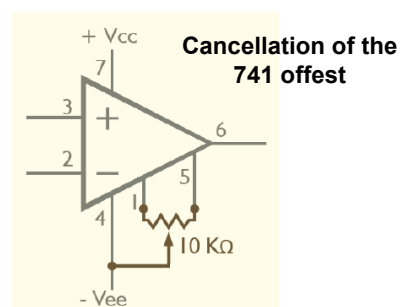
### Operational Amplifier Electrical Symbols



By definition an op amp ideally provides a voltage gain and an infinite input impedance as well as an output impedance equal to zero.

Also the output voltage must be equal to zero when there is no input signal. In this practice, this is not possible because of polarizations and differential amplifier offsets.

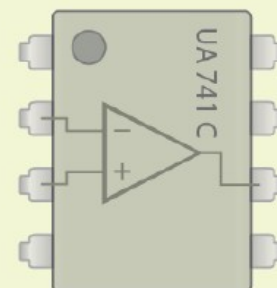
In order to eliminate this drift, that in some circuits will be absolutely indispensable, the manufacturer normally represents a compensation circuit in the integrated's technical characteristic sheet.



### The 741

The 741 Fairchild have denominated uA741 its first improved monolithic amplifier, for generic use. Its easy and low cost have catapulted it until the standard category, and for this reason several manufacturers develop the same operational under slightly different denominations, like MC741, LM741, etc. Nevertheless, it is commonly known and identified simply as 741.

#### 741 pinout



The 741's characteristics offer it the category of generic, it can be highly useful in numerous applications but it is also insufficient for determined exigencies, where a more specialized operational one must look for.

Using it as comparator, you have to mainly take in account the answer speed. The 741 incorporates an internal balance capacitor against oscillations on the signal, but at the same time it reduces and determines the variation speed of the answer voltage, (SR.). In the EDU-015, it is insignificant.

comparators of the EDU-015 this one factor does not become necessary to contemplate it.

#### Table of characteristics and basic parameters common 741

$R_o$	Output Resistance	75 $\Omega$
$R_i$	Input Resistance	2 M $\Omega$
$V_{io}$	Input Offset Voltage	2 mV
$I_{io}$	Input Offset Current	20 nA
$I_{ib}$	Input Bias Current	80 nA
GBP	Gain Bandwidth Product	1 MHz
$A_{vd}$	Large Signal Voltage Gain	200 V/mv
CMR	Common Mode Rejection Ratio	90 dB
SR	Slew Rate	0,5 V/ $\mu$ s

**Practice 1 - The Comparator.**

By its application, the operational one can be distinguished in two types of circuits, linear and nonlinear.

In the linear circuits composed by an operational, the output has the same signal form that the input, without any operational saturation. Some examples of linear circuits developed with op amp are differential amplifiers, non inverter amplifier, inverters, current amplifiers, filters, automatic gain control circuits, etc.

Circuits nonlinear composed by operational are those in which normally the output signal form is different from the input one, because in some moment of the input cycle it enters in saturation mode. In the present practice it will be described the operational's operating process as Comparator, an example of nonlinear application. In others it can be mentioned integrator, waveform converters, differentiator, signal generator, etc.

The comparator, as its denomination indicates, allows to compare two voltages and to identify the lower or the higher, according its configuration.

The output operates between two states, high level or low level. Both always correspond respectively with the positive feeding voltage, (+Vcc), and with the negative (-Vee). One of them will appear in the output as a result of the comparison.

All the operations are not apt to operate as Comparator. As it were described previously, the 741 has an internal balance capacitor to protect it against interferences on the signal result. A protection in a comparator is unnecessary and limits the answer speed in the comparison. This parameter is basic in applications where the comparator must be very fast (for instance for an A/D converter). For this reason, some operational don't have the compensation capacitor or allow to externally establish it on a integrated's pin.

The answer speed, (SR.), is 0.5 V/us in the 741, but there are other specialized integrated, like the LM361, ME521, LT1016 or the AM-685, where the SR. is under 14ns.

However, for applications where the comparison is not fast like for EDU-015 practices of the, the 741 it will be highly sufficient.

A comparator can operate with two variable input voltages, or regarding a reference voltage. The reference voltage is established on one of the two inputs, whereas the variable voltage to compare is applied to the free input.

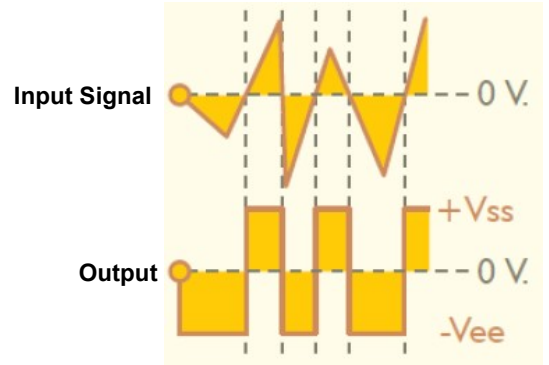
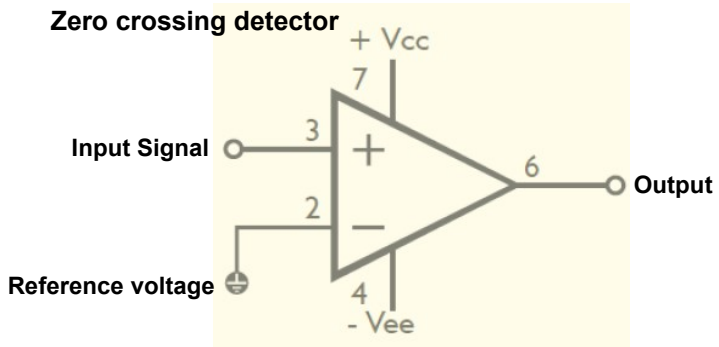
The basic example would be the crossing detector by zero. If the input inverter is driven to ground, any positive signal will provoke a high level output, whereas a negative signal input will place the output to low level. In other words, ideally, the output will switch from high level to low level, each time the input pass by zero.

Crossing Detector by zero

Input signal

Reference voltage

**Zero crossing detector**

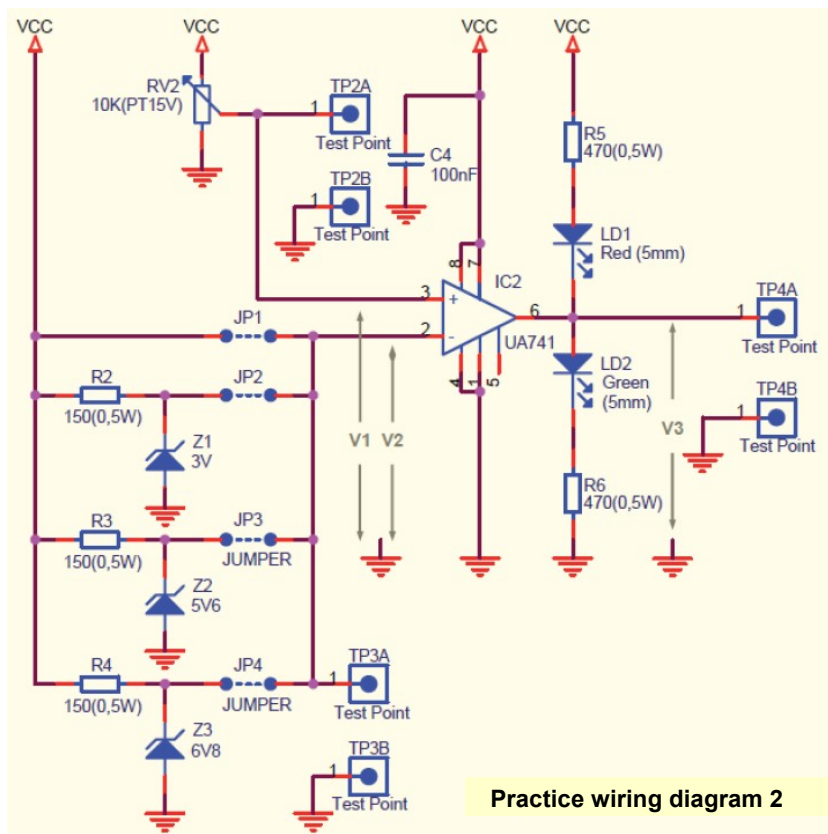


**Practice 2 - Switching point different to zero.**

When the reference voltage is not zero, the comparator doesn't operate as crossing detector. More over, if the voltage reference changes, and then both inputs are under variable values, the comparator becomes more complex.

Practices 2 and 3 use a single power supply, (-Vee connects to ground), for this reason the difference of the answer regarding the previous example is higher.

Practice 2 shows how operate an operational with switching point different from zero and with a single power supply. What happens when only the input signal varies regarding the reference, or what happens when the reference input is established on the non inverter input



**Practice wiring diagram 2**

To monitor the input voltage, (V1), select an oscilloscope channel between TP2A and TP2B. Place another channel in the output, between TP4A and TP4B, (V3). Finally, the reference voltage, (V2), through a voltmeter between TP3A and TP3B. The jumper allows to select among four, the reference voltage. Three are fixed by Zeners and the last one is directly connected to Vcc, (9 V. approx). The RV2 potentiometer, adjust between 0 and Vcc the voltage on the non inverter input. The objective of this practice is to verify for each reference voltage, elaborating an input/output graph, in which the comparator point changes from low level to high.

**Note** . Being supplied by a single power supply, and by the internal fall, the 741's high and low output levels are approximately between 2.5 and 7 V. For this reason, at high level only LED LD2 will light on, and at low level LD1 and LD2 partially light on.

### Practice 3 - Windows Comparator

The window comparator allows to establish through two reference voltages, a threshold or voltage window only between which the output will operate.

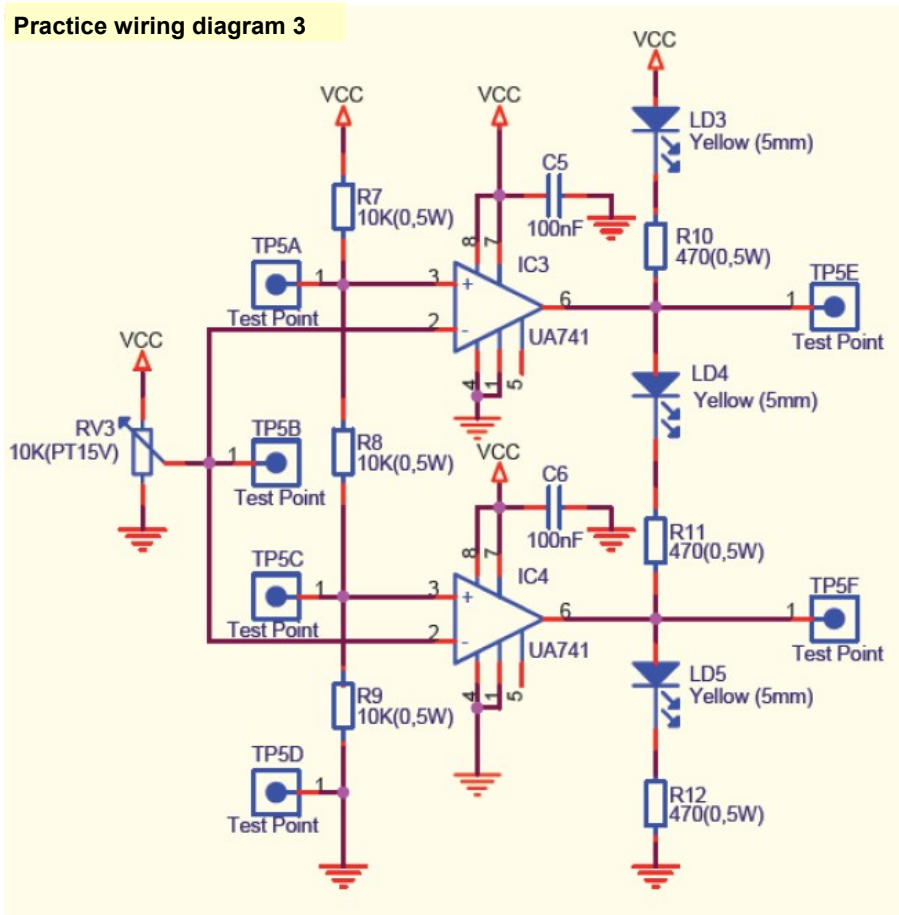
The circuit is obtained connecting two comparators each one with different reference voltage.

The common input voltage, adjustable between 0 and Vcc is injected to inverter inputs of both operational through RV3 potentiometer.

The reference voltages are established through a voltage divisor 1 to 3 for R7, R8 and R9. Through this network, the reference voltage in IC3 is  $2/3 V_{cc}$ , whereas the reference voltage. in IC4 is  $1/3 V_{cc}$ .

The different voltages monitoring is done regarding a single negative or ground, (TP5D). The first operational V. reference, (IC3) must to be placed in TP5A. The second operational V. reference, (IC4), in TP5B. The input voltage is obtained through TP5B. The IC3 output reading is obtained in TP5E, and the IC4 one on TP5F.

The comparator result or window will be obtained between the two outputs of both comparators, (between TP5E and TP5F). Nevertheless, the practice has been configured to establish a truth table, to indicate which input voltage ranges are for IC3, IC4 or both, consequently lighting on each LED and illustrating widely the window comparator operating mode.



**NOTE:** This kit is recommended for children aged 12 years, always accompanied by an adult.