EDUCATIONAL MODULES

For LEARNING and to PRACTISE the ELECTRONICS

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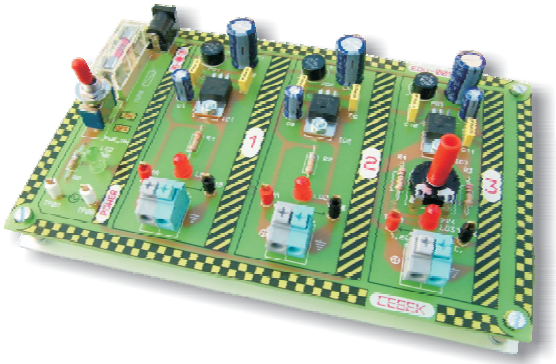
EDU-009. Linear Power Supplies.



EDU-009

The Edu-009 practice describes the process to convert the alternate current form the mains into a discontinued voltage, using fix and variable voltage regulators. Applying the 78XX and LM317 family, in three practices you can see different parameters required by the power supply for the regulation process.
An original instruction manual from manufacturers is included, to allow the student to familiarize with control parameters and these components' design.

- **Practice 0.** Power supply definition; Parts dividing it and description of different elements composing it.
- **Practice 1.** 5 V DC Power supply based on the LM7805 regulator. Dropout voltage, ripple voltage, and voltage after the regulator.
- **Practice 2.** 9 V DC Power supply based on the LM7809 regulator. Comparison regarding the previous one, ripple voltage.
- **Practice 3.** Variable Power supply based on the LM317 regulator. Filter Capacitors function and design of the voltage adjustment.

EDU-009. Linear Power Supplies

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 :N°+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.

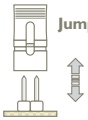
According to the colour of the switch, you can control the voltage, the current

Power supply
Red

Current
Blue

Voltage
Yellow

Logical
Green



Jumper.

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

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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.

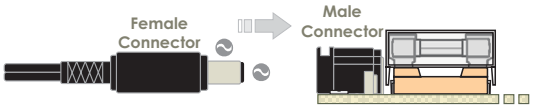
Do not make connections not indicated in the instruction manual to avoid to damage the circuit.
If the Led of the power supply "PWR" doesn't light on or if its function suddenly stops, you have to quickly disconnect the power supply for the device and check there is any short-circuit as well as the fuse's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

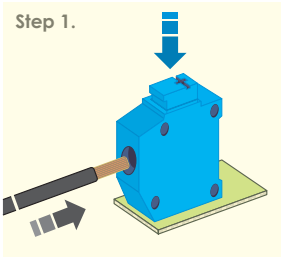
Module Supply.

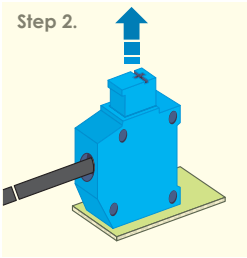
The module has to be supplied at 12 V AC. You have to use a transformer with this voltage on the secondary and a current at least 3A.
The circuit's supply is done only through the male connector placed on the board, **do not inject any other kind of signal on any other terminal placed on the circuit.** Once supplied, the circuit will offer necessaries voltages to experiment in each practice.
For the connexion of the module's power supply, you have to use the included cable with a male connector at one extremity and with wires in the other extremity, where you have to connect the transformer. **Note:** The circuit includes a 3 A fuse.



Output

Output terminals accepts 2,5mm as maximum section. The cable is fixed by pressure, instead of screw. This process is done pushing down the connector's plunger, then the space reserved to fit the connector will open UP. Once the terminal inserted to the deep and the plunger is free, the conductor remains fixed and in electrical contact with the circuit.





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Necessary material.

It is not required any special material neither additional components to use and make experiments with this module. You only need necessary measure instruments to obtain and contrast values obtained from the practice and the power supply (transformer).
For this module, it is also necessary an oscilloscope with one or several channels. If you also have a voltmeter you can also use it, nevertheless you can't appreciate several alternate signals results.

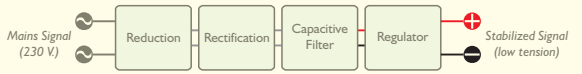
Bibliography.

- Electronics principles. E. McGraw-Hill. Author: Albert Paul Malvino.
- In Google: 7812 National | LM317 National

Previous concepts.

A power supply is defined as a circuit which supply a constant and stabilized voltage for the current required by the load. Normally, the power supply starts form the connexion to the electrical mains and you have to finally insure a low voltage electrical supply for the connected device.
The process to convert a A.C signal from the mains into a stabilized low voltage D.C signal can be divided in different blocks, each one doing a specific function and therefore requiring some specific considerations in its design.

Drawing in blocks of a power supply.

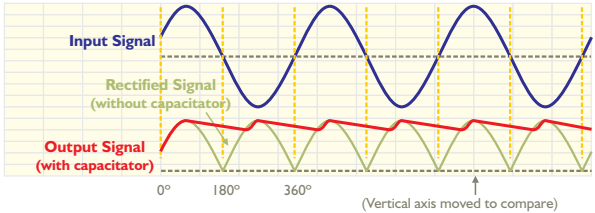


Reduction. The first important element in the design of a power supply is the transformer, which function is to reduce the mains voltage into a value significantly inferior. On the market, there are an infinity of models with different output voltages. Because of the power loss, a transformer doesn't supply always the same voltage but it will depend on the applied load. In the technical documentation of each manufacturer, you can find the voltage offered in the secondary for a determined consumption level, and the voltage of the secondary in empty. The margin between these two values and the allowed current to circulate by the transformer will be basic elements to select a power supply and after power supply's parameters.
Some transformers models, as encapsulated, offer the output voltage value in VA (volts per ampere). For instance, a 24 VA transformer at 1A, but if the consumption is 2 A, the supplied voltage will be 12 V.

Rectification. Because of its high importance and extension, the rectification process is exclusively explained and described in the educational module ref EDU-006.
The rectification is done when the negative half cycle of the alternate signal is inverted regarding the positive half cycle, duplicating its frequency.
This method, with four diodes connected in braid, as it is indicated in the diagrams of the practices, over coming other diodes configurations with a lower output and it is named rectifier bridge. The industrial field encapsulates it as component this

Previous Concepts. (Continuation).

configuration, make it as a standard and basically classifying different models according to the maximum circulation current.



Capacitive Filter. The obtained signal after the rectifier bridge is a pushing voltage, far away from a minimally stabilised voltage. Nevertheless, adding the suitable capacitor, because of the component's load-unload, you can avoid that the voltage will reduced under a determined level. Graphically, you can see more clearly that the signal, after the capacitor, is converted into an almost-continuous voltage with the characteristic form of saw teeth.

To calculate a capacitor you have to start from the balance determined by the overload current and the nominal current of the rectifier bridge. The overload current is the produced one when initially the capacitor is discharged, actuating like a momentary shortcircuit. The more the capacitor's capacity is, the more is the time with the overload current at high level; being possible to require more than one operating cycle and therefore to exceed limits of the rectifier bridge's nominal current. It is necessary to remember that 1 cycle = 20 msec, (1/50 Hz).

By an other side, higher the capacitor capacity is and higher will be the ripple answer after the filter. The balance is normally established with the 10% rule, therefore, to calculate the capacitor's value you have to obtain a peak to peak ripple voltage equal at 10% of the peak to peak voltage of the secondary.

The formula to calculate the overload current requires the value of the Thevenin resistance (Rth), composed by the diodes' resistance and the transformer's winding. In the practice, the winding resistance can be obtained though an ohmmeter and the rectifier bridge one, dividing the Vf value between IF, that you find in the documentation of the manufacturer. For the design, you have to guarantee that the overload current produced don't never over pass the limit of the rectifier bridge's nominal current. The designer will determinate the capacitor's capacity and/or the power of the selected rectifier bridge.

Capacitive Filter

$$Vrz = \frac{Ic}{2(Frz) \times C}$$

Overload Current

$$Iovf = \frac{V_2}{Rth}$$

Iovf= Overload Current.
Vrz= V. Ripple.
Ic = Max. Current Load

V_2= V. Secundary
Frz = Ripple Frequency, (Linear Freq.)
C= Capacitator.
Rth = R. Thévenin

Previous concepts. (Continuation 2).

Regulator. The function of the regulator is to supply a determined voltage level and to submit the obtained signal after the capacitor to a definitive filter which will considerably reduce the ripple, and to finally offer a voltage completely continuous. Available in different encapsulated transformer, normally with a pins configuration not superior to 3 pins, it will supply an output voltage and current fenced by the manufacturer for each model. More over, it includes a current limitation, thermic protection, etc…

As most important parameters in a power supply, you have to take in account the "Load Regulation" and "Mains Regulation".

The load regulation indicates the alteration of the voltage value in the load, produced according to its consumption demand.

The mains regulation indicates the percentage of the alteration produced in the load voltage regarding the fluctuation between the minimum and the maximum I the mains. Manufacturer of some models offers both parameters in rank mode, according to the load and mains conditions.

S you can appreciate in the component's characteristics, the 7805 model offer a 10 mV load regulation for a 5mA at 1,5A load current. The mains regulation = 3 mV for a 17,5 at 30V input voltage.

Electrical Characteristics LM78XXC (Note 1: $0°C \le T_J \le +125°C$, unless otherwise noted.)

Symbol	Parameter	Conditions	5V Min	5V Typ	5V Max	12V Min	12V Typ	12V Max	15V Min	15V Typ	15V Max	Units
	Output Voltage		5V			12V			15V			
	Input Voltage (unless otherwise noted)		10V			19V			23V			Units
V_O	Output Voltage	$T_J = 25°C$, 5 mA ≤ I_O ≤ 1A	4.8	5	5.2	11.5	12	12.5	14.4	15	15.6	V
		5 mA ≤ I_O ≤ 1A, $P_D \le 15W$, $V_{MIN} \le V_{IN} \le V_{MAX}$	4.75	5	5.25	11.4	12	12.6	14.25	15	15.75	V
ΔV_O	Line Regulation (Regulación de red)	I_O = 500 mA, $T_J = 25°C$, ΔV_{IN}		3	50		4	120		4	150	mV
				(7 ≤ V_{IN} ≤ 25)			(14.5 ≤ V_{IN} ≤ 30)			(17.5 ≤ V_{IN} ≤ 30)		V
		$0°C \le T_J \le +125°C$, ΔV_{IN}			50			120			150	mV
					(8 ≤ V_{IN} ≤ 20)			(15 ≤ V_{IN} ≤ 27)			(18.5 ≤ V_{IN} ≤ 30)	V
		$I_O \le 1A$, $T_J = 25°C$, ΔV_{IN}			50			120			150	mV
					(7.5 ≤ V_{IN} ≤ 20)			(14.6 ≤ V_{IN} ≤ 27)			(17.7 ≤ V_{IN} ≤ 30)	V
		$0°C \le T_J \le +125°C$, ΔV_{IN}			25			60			75	mV
					(8 ≤ V_{IN} ≤ 12)			(16 ≤ V_{IN} ≤ 22)			(20 ≤ V_{IN} ≤ 26)	V
ΔV_O	Load Regulation (Regulación de carga)	$T_J = 25°C$, 5 mA ≤ I_O ≤ 1.5A		10	50		12	120		12	150	mV
		250 mA ≤ I_O ≤ 750 mA			25			60			75	mV
		5 mA ≤ I_O ≤ 1A, $0°C \le T_J \le +125°C$			50			120			150	mV
V_D	Dropout Voltage	$T_J = 25°C$, I_{OUT} = 1A		2.0			2.0			2.0		V
R_O	Output Resistance	$T_J = 25°C$		8			18			19		mΩ
	Short-Circuit Current	$T_J = 25°C$		2.1			1.5			1.2		A
	Peak Output Current	$T_J = 25°C$		2.4			2.4			2.4		A
	Average TC of V_{OUT}	0°C ≤ T_J ≤ +125°C, I_O = 5mA		40			70			90		mV/°C
V_{IN}	Input Voltage required to maintain line regulation	$T_J = 25°C$, I_O = 1A	7.5			14.6			17.7			V

Dropout Voltage. Is the minimum necessary input voltage to guarantee the regulator's operating mode. In 78XX and LM317 models, the Dropout = 2V. In the practice 2, for instance, (7805), the regulator's input voltage has to be

Practice 0. Common input circuit.

The EDu-009 module is divided in 3 power supplies, all of them share the same input voltage, fuse and switch, but the ground is different…

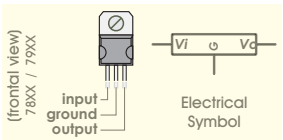
Place a channel of the oscilloscope between point test TP0A and TP0B, To adjust the oscilloscope you can configure it with times basis of 2 ms and adjusted to a 5 or 10 V/Div, AC, opening.

The oscilloscope will display the transformer's output signal, the A.C common input for the three power supplies, before to be rectified and regulated.

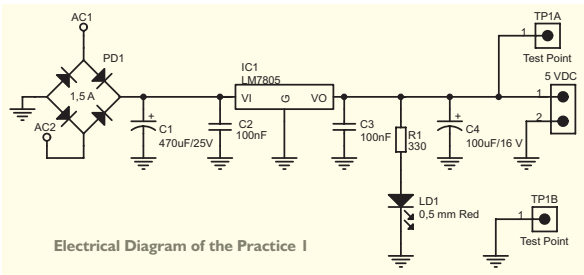
Linear Power Supplies.

Practice 1 and 2. 5 and 9 V. Power Supply

The integrated regulators can be divided in two parts, according to the output type; fix or variable. The fix ones supplies a determined voltage value establish in origin and it can be positive or negative according to the model. Between positive fix regulators the 78XX family is the highly important, where XX indicates the fix output voltage value. 5V for the 7805, 12V for the 7812, etc….The same type of 79XX family, offer negative voltages.



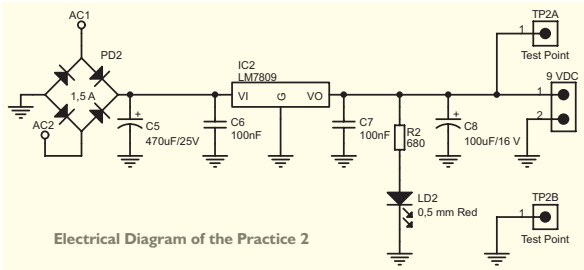
The aim of this practice is to visualize the effect of 7805 and 7905 regulators on a signal coming from a rectifier bridge and the capacitive filter.



Electrical Diagram of the Practice 1

Apply the channel N°1 of the oscilloscope between the 7805's input pin and the central one, (ground). The channel 2has to be applied between the point test TP1 or TP2 according to the practice. The oscilloscope's adjustment will remain in dual visualization, times basis selected in 2 msec, and 0,2V/div AC in the channel N°1 and 5mV/div AC in the channel n°2.

The signal of the first channel will indicate the voltage ripple before the regulator, approximately 240mV in empty, after this one (the channel n°2), the ripple will disappear,



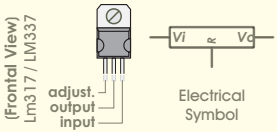
Electrical Diagram of the Practice 2

and displaying a ripple at approximately 0,2mV.

If you make the same read for the 7809 model, the result will be almost the same, because the 78XX family offers a similar answer. To make vary the result, you only have to apply a load to power supplies.

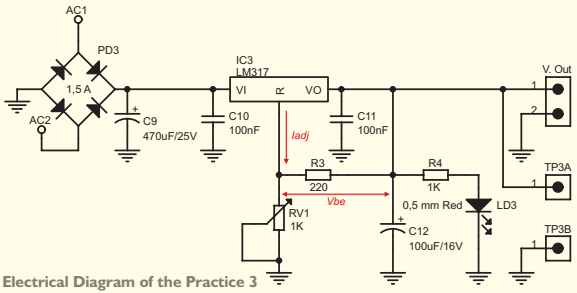
Practice 3. Variable Power Supply.

Among variable type regulators, models LM317 and LM337 are very popular and used in the industrial field, because without increasing the pins number, it is possible to externally adjust the output voltage through the calculus of two configuration resistors.



The practice uses a LM317 model, with the same pins number and similar electrical symbol, but with a different pins assignation regarding the 78XX family. Even there is other encapsulated, the indicated one in the drawing is the most common.

The practice 3 contrasts the practical result of the resistors calculus in the output voltage adjustment. The exercise had to start placing a DC voltmeter between point test TP3A and TP3B, where you can visualize the value of the power supply's output voltage.



Electrical Diagram of the Practice 3

As concern the design of the regulator's part, in a fix or variable power supply, you have to maintain two disconnection capacitors at the entrance and the exit of the transformer. Both are necessary to avoid the inductance caused by the capacitive filter. In the practice C10 and C11 offer this function. Normally, its value is 100nF, although if some manufacturers advise to use a 220nF capacitor at the entrance.
The output voltage adjustment in the regulator is obtained through the calculus of the two control resistors. R3 has to guarantee the input current in the adjustment pin. The manufacturer himself, advice the value, for the LM317, is 220 Ohms. The RV1 resistor can be fix or variable to adjust the voltage between two determined values, and its value is obtained applying the output voltage formula.

Output tension calculation

$$Vo = Vref \times \left(\frac{R3 + Rv1}{R3}\right) + Iadj \times Rv1$$

Vo= V. Output
Vref = V. Reference, (manufacturer).

Iadj. and Vref. are parameters communicated by the manufacturer, for the LM317 is 1,25V and 50uA respectively.
Rotating the RV1's axis, the voltmeter will indicate the output voltage change, produced by the resistor's value change.