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POWER SUPPLY DESIGN BASICS

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Aimed at system designers whose interest focusses on other fields, this note reviews the basic power supply design knowhow assumed in the rest of the book.

In mains-supplied electronic systems the AC input voltage must be converted into a DC voltage with the right value and degree of stabilization.

Figures 1 and 2 show the simplest rectifier circuits. In these basic configurations the peak voltage across the load is equal to the peak value of the AC voltage supplied by the transformer's secondary winding. For most applications the output ripple produced by these circuits is too high. However, for some applications - driving small motors or lamps, for example - they are satisfactory.

If a filter capacitor is added after the rectifier diodes the output voltage waveform is improved considerably. Figures 3 and 4 show two classic circuits commonly used to obtain continuous voltages starting from an alternating voltage. The Figure 3 circuit uses a center-tapped transformer with two rectifier diodes while the Figure 4 circuit uses a simple transformer and four rectifier diodes.
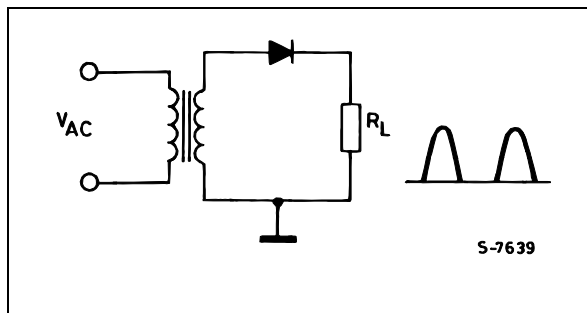
Figure 1 : Basic Half Wave Rectifier Circuit.

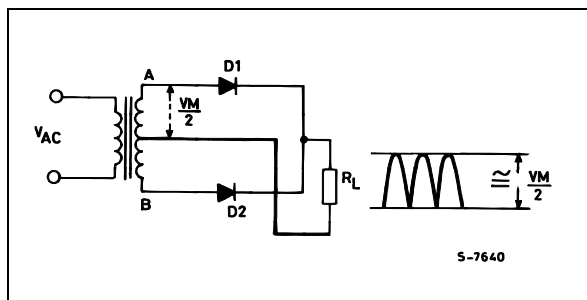**Figure 2 :** Full Wave Rectifier Wich uses a Center-tapped Transformer.

Figure 3 : Full Wave Rectified Output From the Transformer/rectifier Combination is filtered by C1.
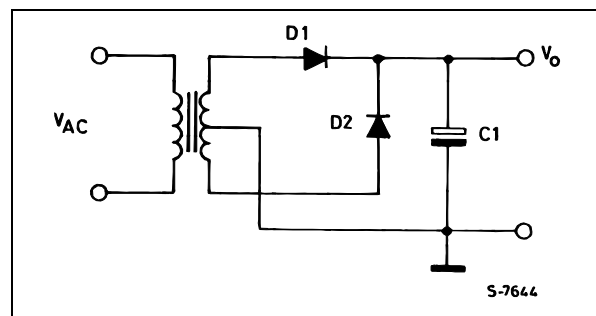

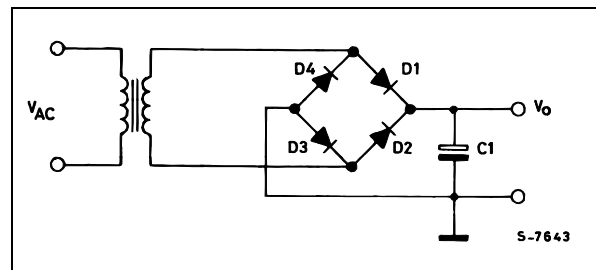**Figure 4 :** This Circuit Performs Identically to that Shown in Figure 3.

Figure 5 shows the continuous voltage curve obtained by adding a filter capacitor to the Figure 1 circuit. The section b-c is a straight line. During this time it is the filter capacitor that supplies the load current. The slope of this line increases as the current increases, bringing point c lower. Consequently the diode conduction time (c-d) increases, increasing ripple. With zero load current the DC output voltage is equal to the peak value of the rectified AC voltage.

Figure 6 shows how to obtain positive and negative outputs referred to a common ground. Useful design data for this circuit is given in figures 7, 8 and 9. In particular, the curves shown in Figure 7 are helpful in determining the voltage ripple for a given load current and filter capacitor value. The value of the voltage ripple obtained is directly proportional to the load current and inversely proportional to the filter capacitor value.

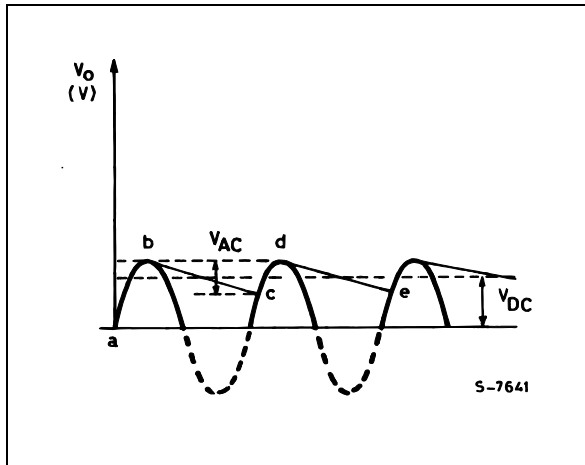**Figure 5 :** Output Waveforms from the Half-wave Rectifier Filter.

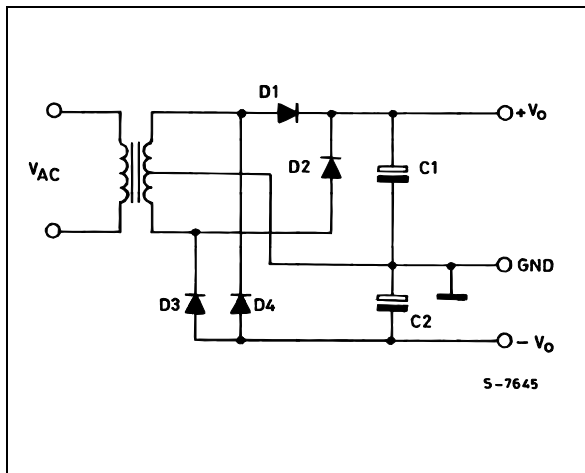**Figure 6 :** Full-wave Split Supply Rectifier.

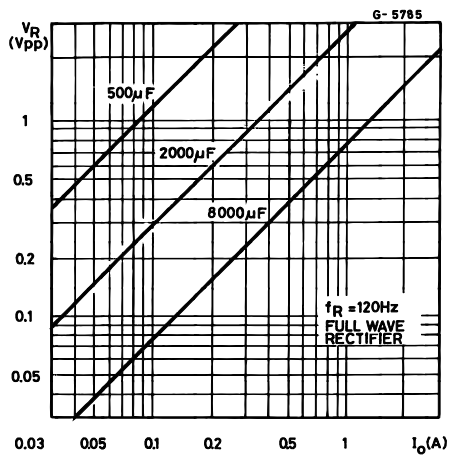**Figure 7 :** Ripple Voltage vs. Filter Capacitor Value (full-wave Rectifier).

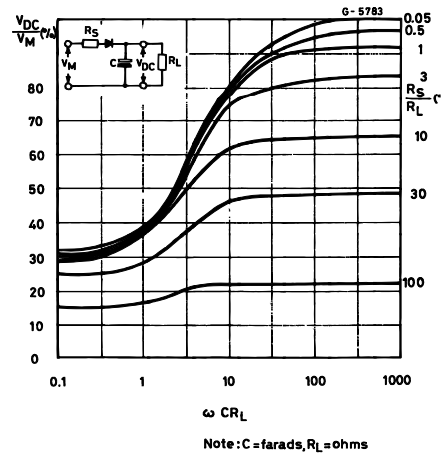**Figure 8 :** DC to Peak Ratio for Half Wave rectifiers.

Note : C = farads, R_L = ohms

Figure 9 : DC to Peak Ratio for Full-wave Rectifiers.
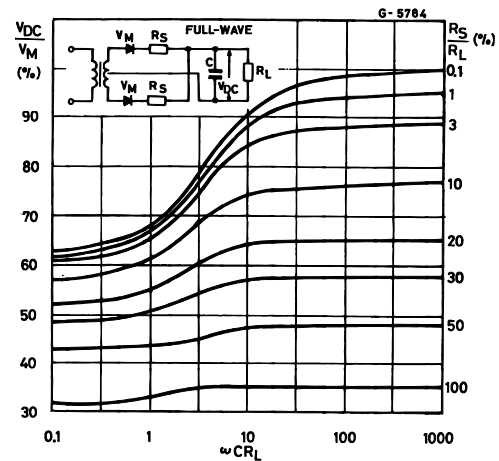
Figure 10 : DC Characteristics of a 50 VA Non-regulated Supply.

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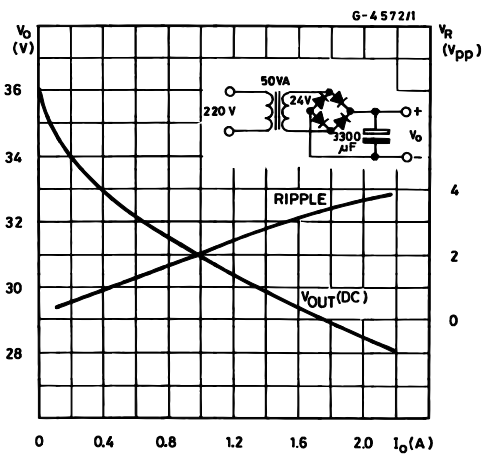MICROELECTRONICS

Table1.

Mains (220V)	Secondary Voltage	DC Output Voltage (V_O)		
		$I_O = 0$	$I_O = 0.1A$	$I_O = 1A$
+20%	28.8V	43.2V	42V	37.5V
+15%	27.6V	41.4V	40.3V	35.8V
+10%	26.4V	39.6V	38.5V	34.2V
	24V	36.2V	35V	31V
−10%	21.6V	32.4V	31.5V	27.8V
−15%	20.4V	30.6V	29.8V	26V
−20%	19.2V	28.8V	28V	24.3V

The performance of a supply commonly used in consumer applications - in audio amplifiers, for example - is described in figure 10 and table 1.

When a low ripple voltage is required an LC filter network may be used. The effect on the output voltage of this addition is shown in figure 11. As figure 11 shows, the residual ripple can be reduced by 40 dB. But often the inductor is costly and bulky.

Often the degree of stability provided by the circuits described above is insufficient and a stabilizer circuit is needed. Figure 12 shows the simplest solution and is satisfactory for loads of up to about 50mA. This circuit is often used as a reference voltage to apply to the base of a transistor of to the input of an op amp to obtain higher output current.

The simplest example of a series regulator is shown in Figure 13. In this circuit the transistor is connected as a voltage follower and the output voltage is about 600 - 700mV lower than the zener voltage. The resistor R must be dimensioned so that the zener is correctly biased and that sufficient base current is supplied to the base of Q1.

For high load currents the base current of Q1 is no longer negligible. To avoid that the current in the zener drops to the point where effective regulation is not possible a darlington may be used in place of the transistor.

When better performance is required the op amp circuit shown in Figure 14 is recommended. In this circuit the output voltage is equal to the reference voltage applied to the input of the op amp. With a suitable output buffer higher currents can be obtained.

The output voltage of the Figure 14 circuit can be varied by adding a variable divider in parallel with the zener diode and with its wiper connected to the op amp's input.

The design of stabilized supplies has been simplified dramatically by the introduction of voltage regulator ICs such as the L78xx and L79xx - three-terminal series regulators which provide a very stable output and include current limiter and

thermal protection functions. Figures 16, 17 and 18 show how these circuits are used. Refer to the datasheets for more information.

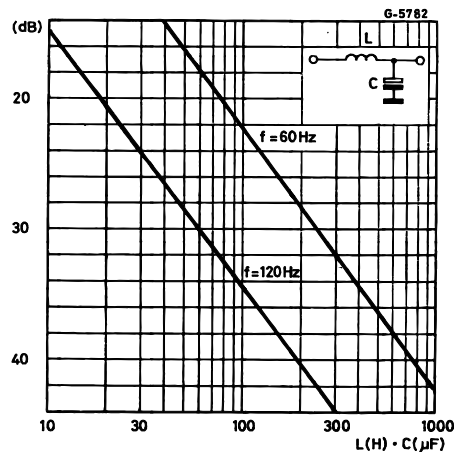**Figure 11 :** Ripple Reduction Produced by a Single Section Inductance-capacitance Filter.

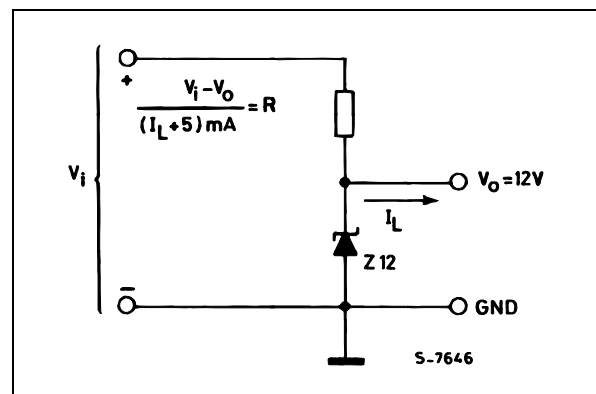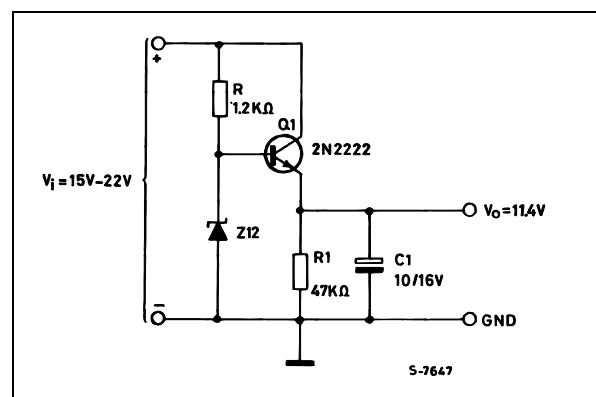**Figure 12 :** Basic Zener Regulator Circuit.

Figure 13 : The Series Pass Zener-based Regulator Circuit can Supply Load Currents up to about 100mA.

Figure 14 : The Op-amp-based Regulator can Supply 100mA with Excellent Regulation.
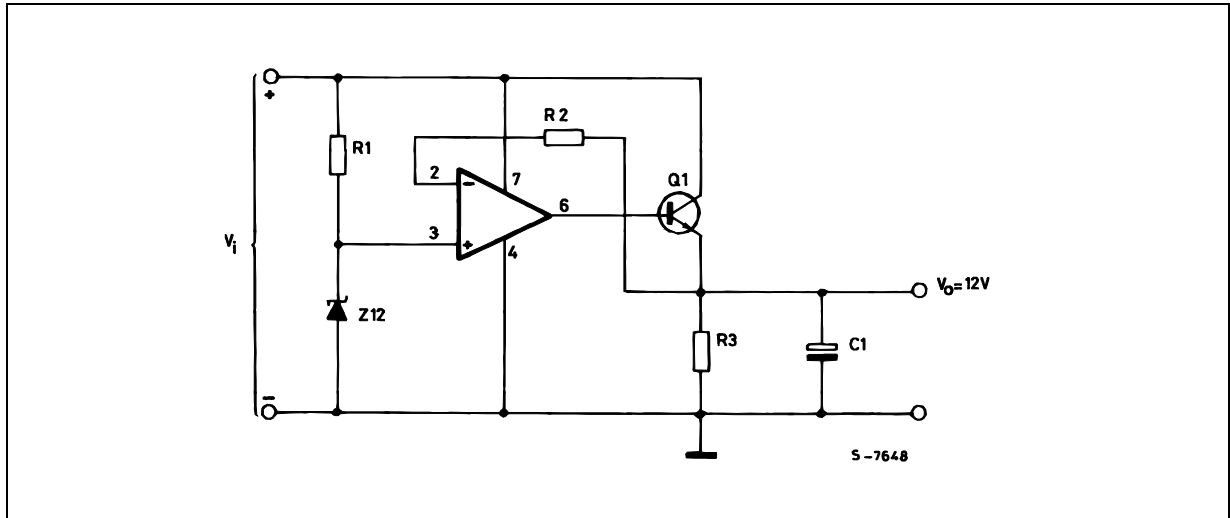

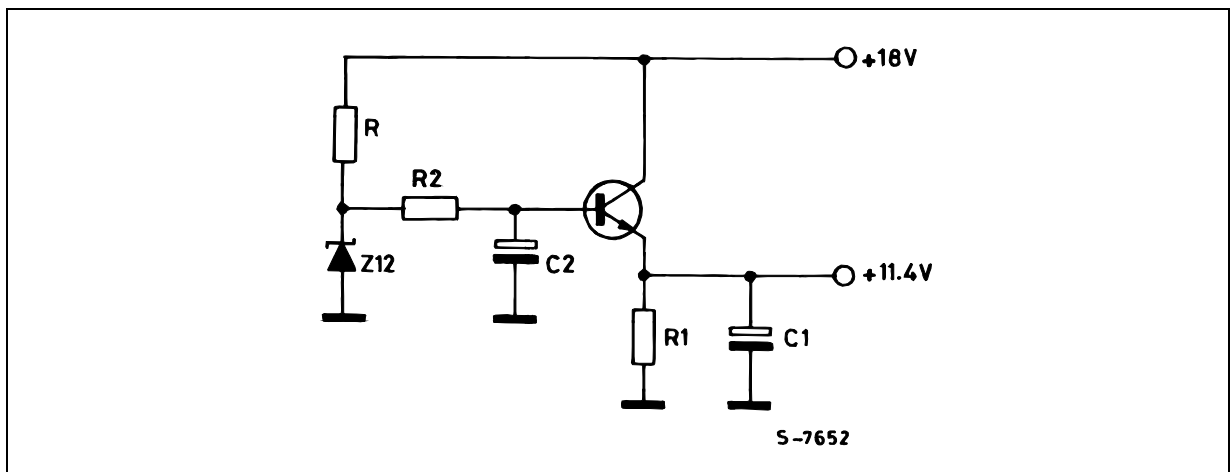**Figure 15 :** Zener Regulator Circuit Modified for Low-noise Output.

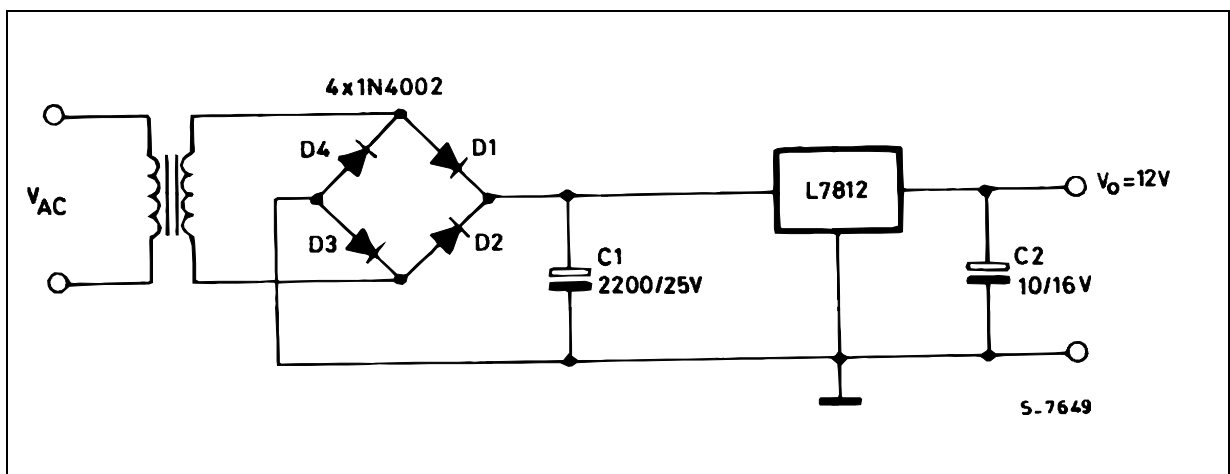**Figure 16 :** A Three Terminal 1A Positive Regulator Circuit is very Simple and Performs very Well.

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Figure 17 : A Three Terminal 1A Negative Voltage Regulator.
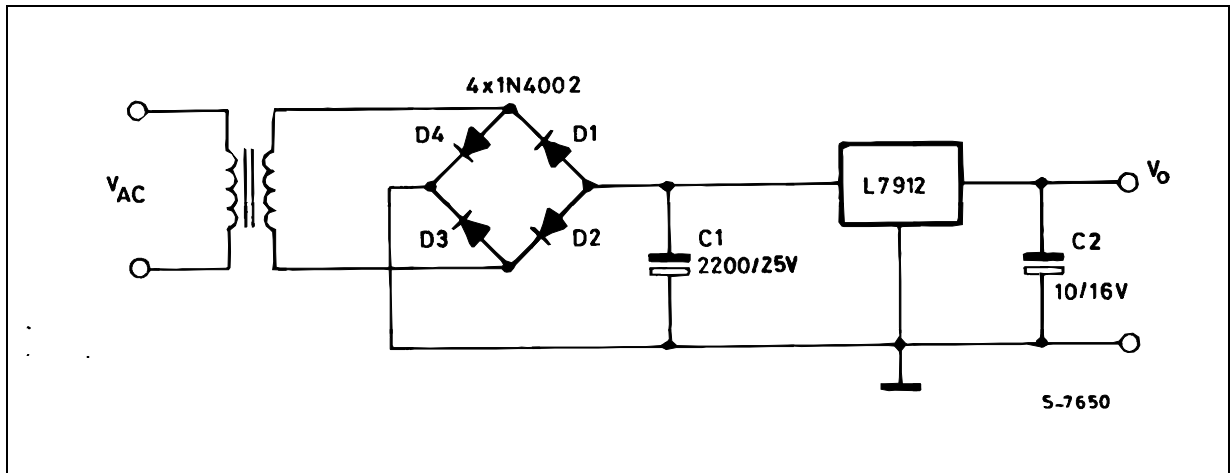
Figure 18 : Complete ± 12V – 1A Split Supply Regulator Circuit.

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