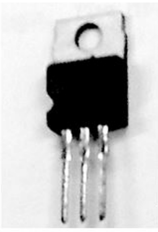
Fixed Linear Regulators

The simplest linear regulators are designed to produce a fixed output voltage. The most commonly-used family of these are the 78xx positive regulators and 79xx negative regulators, where the 'xx' represents the output voltage of the device. Typical values for 'xx' are 05, 06, 08, 09, 10, 12, 15, 18, and 24. These regulators require an input voltage of at least 2 V more than the output voltage. This "overhead" voltage is also called the **Dropout Voltage**, because if the input supply drops below the required value, the output voltage will "drop out", or go below the expected regulated output voltage.

More expensive Linear Regulators do not require as much overhead, and are called **Low Dropout Regulators**, or **LDO Regulators**.

Many of the Fixed Linear Regulators are available in a higher-power package called the TO220 Package, shown below.



TO220 Package

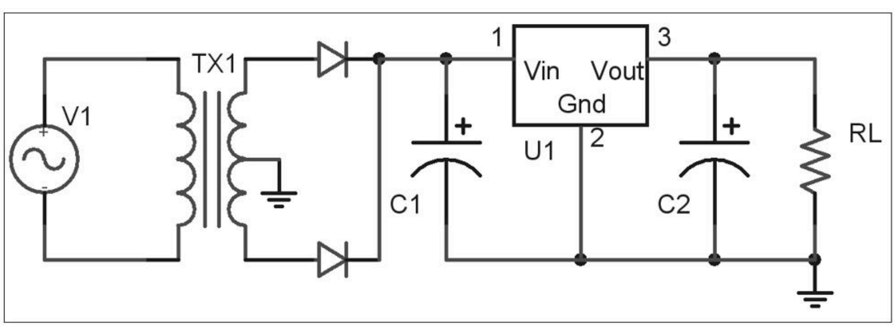
Unfortunately, the pinout for the 78xx devices is different from that of the 79xx devices, as shown below. Also notice that the metal tab is not passive -- it is connected to one of the internal voltages!

Pin	78xx	79xx
1 (left)	Input	Ground
2 (mid)	Ground	Input
3 (right)	Output	Output
Metal Back	Ground	Input

Questions:

1. What is the expected output voltage for an LM7812? 12 V_{DC}
2. What relatively inexpensive device would produce -8 V_{DC} from -12 V_{DC}? LM7908
3. What general group of Linear Regulators can generate an output voltage using an input voltage that is less than 2 V greater than the expected output? Low Drop Out
4. What general group of regulators can produce a voltage higher than the input voltage? Switching Regul…
5. What general group of regulators can produce a negative voltage from a positive voltage? Switching Regul…

Question: Use the schematic below to answer the questions that follow. V1 is 115 VAC, the transformer turns ratio is 6:1, the rectifier diodes have a forward voltage drop of 0.6 V, C1 is 470 μF, and RL is never lower than 75 Ω.



1. Given that U1 is an inexpensive fixed linear regulator, what device number would be required if the output voltage is expected to be +8 VDC? LM7808

2. What is the peak voltage at the output from the rectifier? 13 V_p

3. What is the load current for the heaviest load allowed? 107 mA

4. Based on the maximum load current, what is the expected ripple voltage? 1.89 V_{p-p}

5. How low does the ripple voltage drop to? 11.1 V

6. Given the specified dropout voltage for the device chosen, will the ripple voltage result in dropouts in the output signal?

   No

7. What is the average voltage of the unregulated input signal? 12 V_{DC}

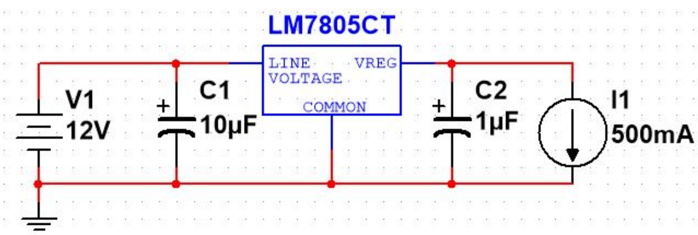
8. Assuming that the RMS voltage of the unregulated input signal is fairly similar to the average voltage, what power is dissipated by U1 when connected to the heaviest allowable load? 427 mW

9. From the manufacturer's specification sheet (https://www.st.com/resource/en/datasheet/l78.pdf), locate this device's ripple rejection. It's called "Supply Voltage Rejection" in this data sheet. 62 dB

10. Use this ripple rejection value to determine the expected ripple for the output signal. 1.5 mV_{p-p}

As can be seen from this last example, the 7808 Linear Regulator is much better at rejecting the input voltage ripple than the Zener Diode regulator on the previous page.

Here's a quick worked example of a fixed regulator circuit that also introduces some of the basic concepts involved in choosing an appropriate heatsink. In this application, a 12 VDC supply is available, but the desired voltage is 5.0 VDC; so an LM7805 has been chosen. The load is expected to draw up to 500 mA from the regulator.



The output voltage, as indicated above and as can be determined from the part number, is +5 VDC.

The device can operate with any unregulated input that provides 2.0 V overhead. In this case, there is an overhead of 7.0 V, so there will be no problems with the device maintaining regulation.

However, power will be an issue. P = IΔV = 500 mA*(12.0 V -5.0 V) = 3.5 W.

Here's a snippet of the datasheet to help us determine if the circuit needs a heatsink.

Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only. Values are at T_A = 25°C unless otherwise noted.

Symbol	Parameter		Value	Unit
V_I	Input Voltage	V_O = 5 V to 18 V	35	V
		V_O = 24 V	40	
$R_{\theta JC}$	Thermal Resistance, Junction-Case (TO-220)		5	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction-Air (TO-220)		65	°C/W
T_{OPR}	Operating Temperature Range	LM78xx	-40 to +125	°C
		LM78xxA	0 to +125	
T_{STG}	Storage Temperature Range		- 65 to +150	°C

Notice that two values are provided related to the dissipation of heat -- one from the "junction" i.e. the silicon to the outside of the component and one from the junction to the surrounding air. At this point, let's work with just the second one to see if we can get away with not using a heatsink.

The change in temperature between the air and the junction can be calculated by multiplying the thermal resistance by the power dissipation; so ΔT = 3.5 W * 65°C/W = 227.5°C. If the ambient temperature is 25°C, the junction temperature will be 252.5°C. However, the operating temperature cannot exceed 125°C, so we will need a heatsink on this circuit.

If we want to keep the temperature at a safe value, say 55°C (the temperature of very hot tap water), assuming a room temperature of approximately 25°C we would need to have an overall thermal resistance of (55°C - 25°C)/3.5 W = 8.7°C/W. Since the thermal resistance from junction to case is 5°C/W, we would need a heatsink with a thermal resistance to air of 3.7°C/W or less. A quick search at digikey.ca turned up the following heatsink, which takes up a fair bit of space and costs about $2.50:

In an actual design, we'd also need to consider the thermal resistance between the IC case and the heatsink, although that can be reduced to the point of being negligible using a thermal paste between the regulator and the heatsink.