Photovoltaic Power Supply

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INTRODUCTION
In an age of dwindling fossil fuels and climate change a lot of attention is being been focussed on renewable forms of energy such as photovoltaic (PV) cells. This article describes a method for obtaining optimal power from a small PV panel using a modified switch mode power supply.

PV CHARACTERISTICS
First let's take look at some PV characteristics. Figure 1 below shows the I-V characteristics at various temperatures at STC. What we're interested in is the voltage at which maximum power can be drawn from the panel. Looking at the 25 Deg. C curve, maximum power occurs at around 19V, and for the 75 Deg. C curve this is about 17V.

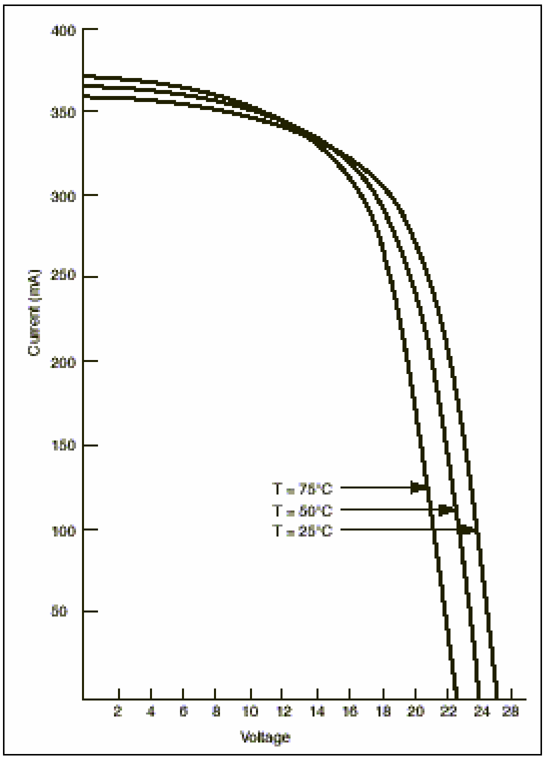

Figure 1 I-V characteristics at various temperatures (amorphous silicon panel)

Similarly the I-V characteristics at various sunlight levels at STC are shown in Figure 2. From Figure 2 it can be seen that the voltage at which maximum power occurs doesn't change significantly with differing light levels. It is assumed at this point that polycrystalline PV cells have similar characteristics to amorphous silicon PV cells.

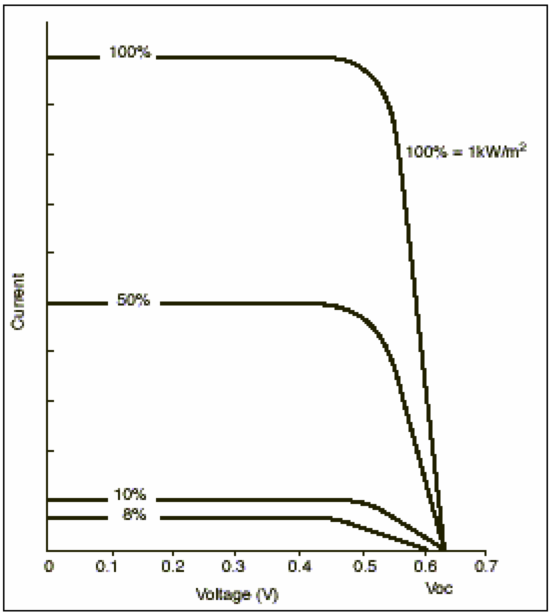

Figure 2 I-V characteristics at various sunlight levels (polycrystalline cell)

We shall conclude that PV voltage could be used as a good approximation for determining maximum power for a given temperature. The voltage at which this occurs we shall call the ‘maximum power voltage’.

POWER CONVERSION

Having established the need to operate the solar panel at its maximum power voltage, all that's required is a device for converting the available power into a voltage and current suitable for driving a load. The load considered here will be a rechargeable battery.

Technically a device for doing this is known as an impedance matcher, but since the solar panel impedance and load impedance are variable, it's easier to think in terms of maximum power conversion. In other words we want to take as much power as possible from the solar panel and convert as much of that power as we can to drive the load.

To do the power conversion we'll use a DC-DC converter using a switch mode regulator. This can be thought of as a transformer that is about 85% efficient and has a real time variable turns ration.

We don't actually know the exact power from the PV panel but we do know it occurs at a given voltage. The power converter therefore controls the voltage on the PV panel by regulating the amount of power delivered to the load (the rechargeable battery).

POWER CONVERTER OPERATION

The block schematic in Figure 3 shows the power (bold arrows) and feedback path of the power converter. The return current paths have been omitted for clarity.

When the PV panel voltage (VI) is higher than Vref, the switch mode regulator (SMR) feed back input (FB) will go proportionally lower. The SMR thinks the output voltage (VO) is too low and compensates by increasing VO to the load (L). The load consumes more power with increasing VO.

More power is drawn from the panel and as a result the panel voltage VI drops, raising the voltage on FB causing the SMR to lower VO. This continues until equilibrium is met.

In reality the change in voltages of VI and FB are finite. VO on the other hand will depend on the state of the load. In the case of a rechargeable battery, VO will be limited to the characteristics of the battery.

Essentially what we have done is to take an off the shelf switch mode regulator and modified it so that instead of regulating the load voltage, it regulates the source voltage.

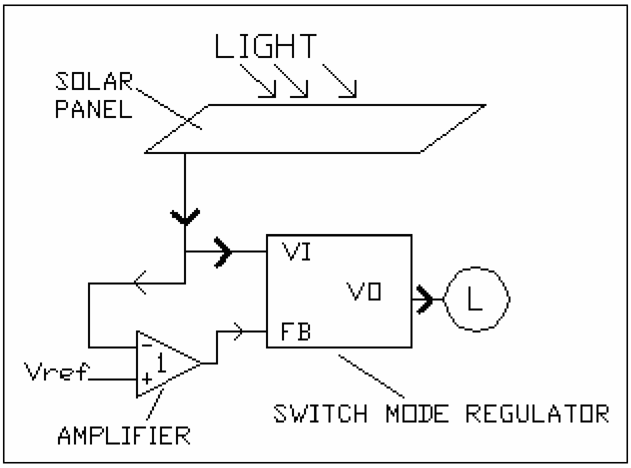

Figure 3 Power converter block schematic

POWER SUPPLY APPLICATION

This application uses a PV panel to charge a lower voltage battery. The power supply therefore has to take the high voltage low current from the PV panel and convert it to a low voltage high current for the load. The converter also maintains the panel at its maximum power voltage.

To do this we shall use an LM2676 mosfet switch mode step down (buck) regulator and LM301 op-amp. The circuit schematic is shown in Figure 4. The circuit operates when power from the PV panel is applied to V+ and 0V. Assuming a 9V rechargeable battery is connect to the output on L+ and L- the LM2676 immediately drives up to the load voltage (i.e. 9V) since the FB input is below its internal reference voltage. As the LM2676 drives more current into the load the supply voltage begins to drop as more power is demanded from the PV panel. When the panel voltage drops below a level set by VR1, U1 begins to drive its output high which increases the voltage applied to the FB input of the LM2676. Once FB reaches the internal reference voltage the LM2676 will maintain the current it’s delivering to the load. Should the PV panel become shaded, V+ will drop due to the reduced power, which in turn will cause FB to increase and the LM2676 to deliver less current.

This circuit can accommodate PV panels with nominal open circuit voltage from 12V to 20V and maximum power of 10W. Rechargeable batteries can be from 6V to 14V. The panel voltage must be at least 4V higher than the rechargeable battery voltage or the circuit may fail to operate.

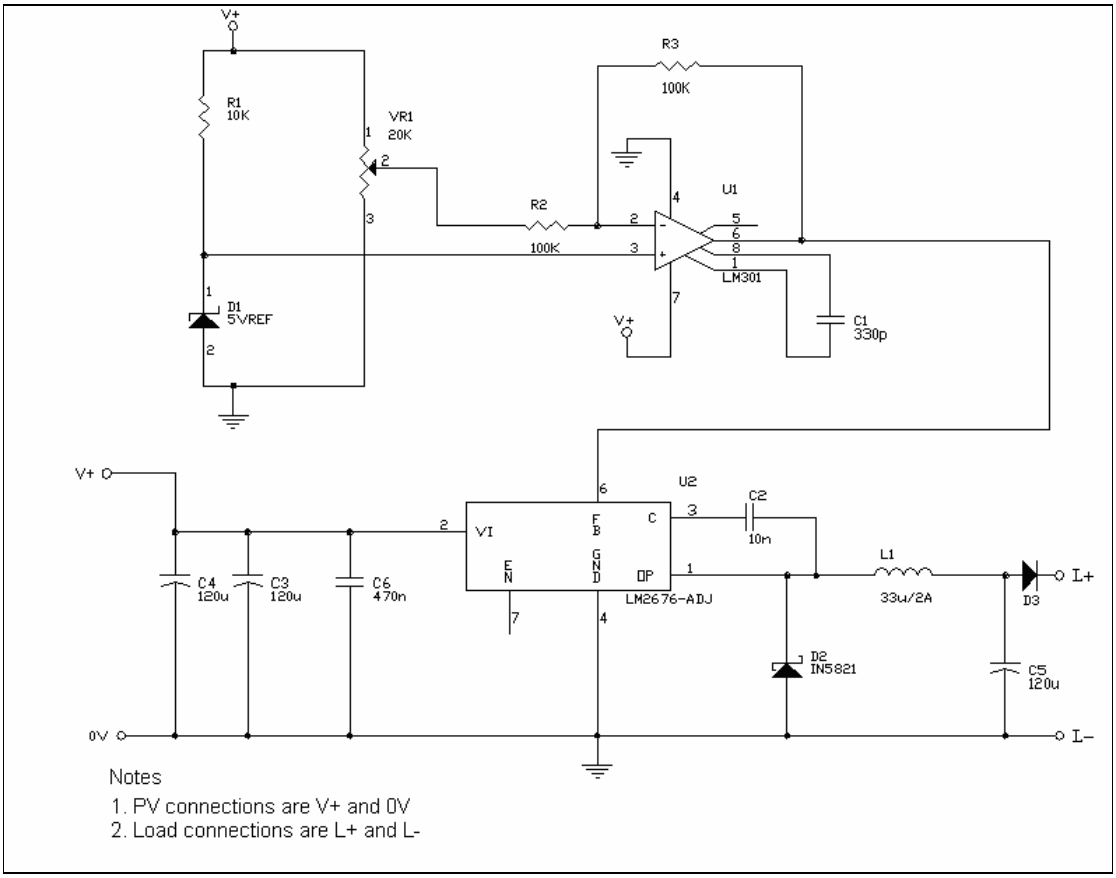

Figure 4 PV power supply circuit schematic

LIMITATIONS

There are a couple of limitations. First, this scheme does not allow for large variation in the PV panel temperature. Should the panel be fitted externally then it will almost certainly exceed the temperature range discussed earlier, not compensating for this represents a loss in efficiency. Second, there is no mechanism to prevent the battery from overcharging. This could be overcome by dumping power into a suitably sized zener diode placed across the battery terminals, or more elegantly, use a resistor diode network and perhaps second op-amp to drive U1 ‘+’ input high when L+ goes over voltage.

GLOSSARY

STC: Standard Test Conditions under which a solar panel is tested is defined as: a solar illumination of 1KW per square meter, ambient temperature of 25 Deg.C and Air Mass of 1.5.

REFERENCES

1. www.summitelectronics.co.uk/gonzalez

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