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Solar Power Optimizer and Battery Charger

Group: 0B5

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Abstract
The utility of Maximum Power Point Tracking [MPPT] for improving the efficiency is mentioned. Solar panels are characterized and buck converter is implemented. The issues of isolated power supply, inductor design are discussed. The control circuit is implemented to control switching of buck converter to do MPPT. Safety measure is taken to ensure good life of battery.

Introduction
The efficiency of a solar panel during normal use is 40-45% as voltage current product is not constant throughout the use. The load may have a V across its terminal leading to a current which doesn't supply maximum power. Analysis of the panel current-voltage relationship leads to an understanding that maximum power can be produced only at a given voltage for a given intensity level. If this condition is achieved, efficiency improves to 85% for a large system of order of 100 watts. The aim of this project is to do **MPPT** [Maximum Power Point Tracking] of Solar panel and transfer the power generated to a battery efficiently.

Solar panel is like a current source which supplies constant current for a wide range of voltage across its terminals. For voltages above 0.8 V_{oc} current tends to fall and is zero at V_{oc}. The power generated is $\mathrm{V}_{\mathrm{ter}} * I$ which is to be maximized. If the power thus generated is directly fed to battery, power stored in the battery will be $\mathrm{V}_{\mathrm{battery}} * I$, where $\mathrm{V}_{\mathrm{battery}} \in$ [10.5 V, 13.5 V]

resulting in losses =.$[\mathrm{V}_{\mathrm{solar}} - V_{battery}] * I$.

The circuit model in its most basic form is given below.

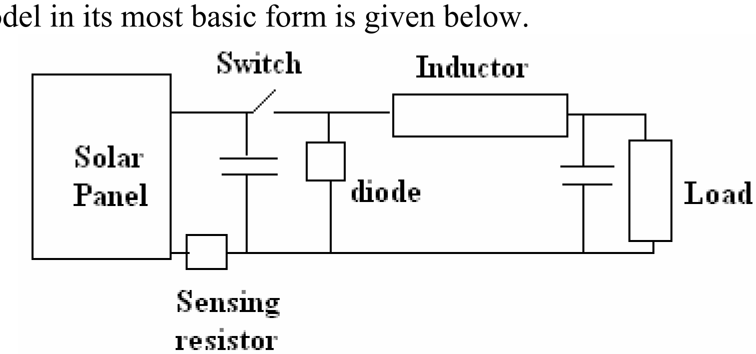


Figure 1: Schematic of model

Equipment Used
Solar panel [2 panels in series connection]
High speed high current diodes
High power n-channel MOSFETS
2.9mH Inductor, Operational amplifiers
110 microfarad and 470 micro farad capacitors
12 V lead acid battery, Voltage dividers
MOSFET driver, IR2110

Solar Panel
The I-V characteristic of the solar panel assembly used is as depicted in the figure. It behaves like a stiff current source up to a certain voltage and then its value falls steeply with rise in voltage. Thus I-V product rises (almost linearly with V) and MPPT is reached beyond which it falls steeply to zero. With change in the intensity of the sunlight the open circuit voltage doesn't change whereas the short circuit current increases with increase in intensity. On plotting the p-v characteristics we obtain a maxima somewhere around half of the open circuit voltage. For our project a 40W solar panel with an open circuit voltage of around 37 volts and a short circuit current of 1.6 amp.

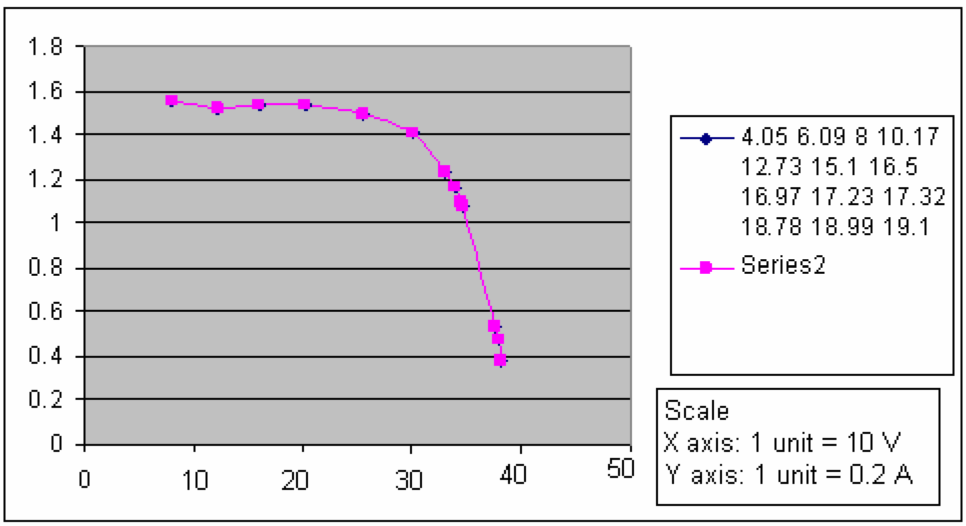


Figure 2: I-V characteristic of solar panel

Buck Converter Control
As the input stage voltage is about 30 volts (for MPPT) and output stage voltage is around 12 volts, efficient transmission is possible through use of power electronics. The duty cycle of the switch is ratio of output V to input V. Hence we can step down voltage. The current ratio is such that the net input power is same as the output power as there are no energy consuming devices in the circuit. Energy generated when switch is on is directly transferred to the load along with energy from the capacitor. Energy is also stored in the inductor. When the switch is off, all generated power is stored in the capacitor and energy from inductor is transferred to the load. Instead of the generic case of a fixed source and a variable load we have implemented with a variable source (solar panel) and a fixed source (battery).

At Steady state,

$$\int_0^T V_{inductor}\,dt = 0; \qquad \text{equation 1}$$

$$\int_0^T I_{capacitor}\,dt = 0; \qquad \text{equation 2}$$

Using equation 1, $DV_{solar} = V_{battery}$

Thus by varying the duty cycle D, V_{MPPT} can be maintained across the panel.

Inductor

Inductor is used to maintain the continuity of current in the circuit feeding the load. It is designed to operate at frequency of 25 kHz, 3A maximum current rating and can be operated in continuous as well as discontinuous modes. As the frequency and current rating is high, ferrite core is used. By using Faraday's law of electromagnetic induction and ampere's circuital law, number of turns and air gap were calculated to be 90 and 1.1mm respectively.

Inductance of the wounded inductor was calculated to be 2.9 mH.

The expression for **L** is given by:

$$L = \frac{V_{solar}(1-D)D}{f(I_{DT} - I_0)}$$

maximum value of L thus calculated = 2.6 mH

The number of turns was calculated to be 90 and thickness of air gap 1.1mm.

Capacitors

Capacitors are needed at the source and the load side to regulate the voltage so that system operates at $V_{ter\min al}$, voltage corresponding to MPPT at source end.

The expression for **C** is given by:

$$C = \frac{I_{solar}(1-D)}{f(V_{DT} - V_T)}$$

where choice of $(V_{DT} - V_T)$ [maximum change in regulated voltage] is on us. Using its value to be 0.4 V at 25kHz, maximum value of C obtained is 100 μF.

Isolated Power Supplies

The circuit needs a 15V supply to run the mosfet driver circuit, 5 V supply for opamps and 5V for microprocessor. 15V is obtained using 7815 and 5V is obtained using 7805.The V_{GS} pulse has to be above 5 V for switching of mosfet. This is achieved by using IR2110.

Safety of Battery

There is R_{sense} at the load end across which voltage is monitored. When the battery gets charged, the current in the battery reduces and gets reflected in V across R_{sense} and is used to switch off the circuit completely to prevent damage to the components.

Control Circuit

The control is implemented using Atmega32L microcontroller. It has an inbuilt ADC and current and voltages sensed are given as input to it.

Algorithm

The current and voltages are sensed across the Solar Panel and their product is maximized. Perturbation and Observation algorithm is used to achieve the objective.

Perturb	D+dD
Observe	V(t+dt), I(t+dt)
If	P(t+dt) > P(t) => D + dD
Else	D – dD, return.

The current is obtained by using R_{sense} across which voltage measure is taken.

IR2110

For switching on a MOSFET a large initial current is required momentarily. The IR2110/IR2113 are high voltage, high speed power MOSFET and IGBT drivers with independent high and low side referenced output channels. A variable pulse width input is provided from microcontroller to Hin(Pin 10) of IR2110 and charge stored in the capacitor is used for starting the mosfet. Mosfet draws an initial charge of around 50 nano coulomb to start.

Sensing circuit

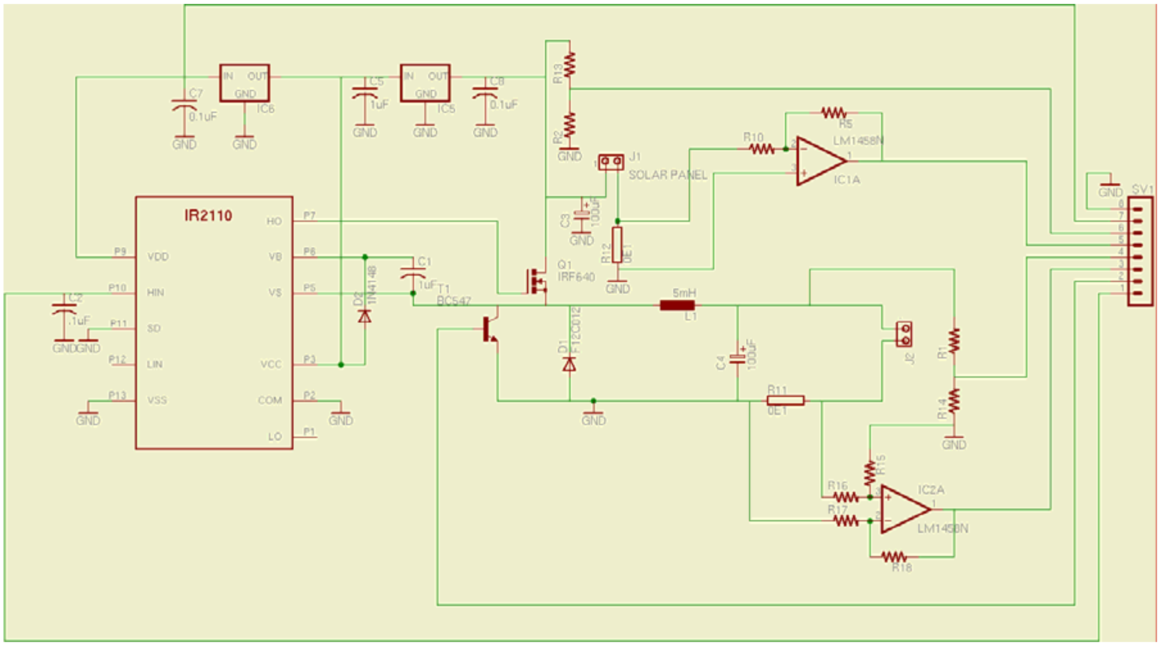
For the control circuit to operate voltage and current measurements are taken at the load and source side. Low value resistances of 0.5 ohm 10 W are used for current measurement. The values so obtained are very small and hence have to be amplified using op-ams[LM458]. One voltage divider is used to step down the solar panel voltage and another is used at the battery side, to a maximum of 3.3 V so that it can be fed to the micro controller.

Conclusion

Attempt was made to improve efficiency of the solar panels by using a scheme that ensures maximum generation of power by the panels followed by transfer of the generated energy to load. This scheme has been used to give improvements of up to 40% for a high wattage system in which power consumed by power electronic components and the microcontroller is very less compared to generated power. Design issues related to component value selection, energy consumption and ground problems were encountered and their solutions achieved.

The system presented is not working as perfectly as desired and there are scopes of improvements in the design which were looked into but couldn't be implemented. The project was overall a good learning experience.

Layout of the circuit



Schematic of the diagram used for MPPT in solar panel

Acknowledgement

We are thankful to Dipankar Sir for helping us through out the project and bringing to our knowledge many of the aspects of the designs we would have otherwise overlooked. We are also thankful to all the TAs, Professors in WELL and students in the power lab for helping us develop the understanding of the project and also letting us know the sources from were the requirements could be procured.

References

[1] www.alldatasheet.com
[2] www.irf.com
[3] www.ti.com
[4] www.google.com