QST in DEPTH
QST Solar Powered Repeater Article

The following paragraphs are intended for the reader who wishes additional information about the subject of the corresponding QST article. The authors have included data that may be of use to hams considering solar projects or who may just want to read further on the topic.

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1) Charge Controller Discussion

PWM Charge Controller

Pulse Width Modulation uses a rapid series of power pulses from the controller to charge the battery. The pulse width and speed selected by the controller depend upon the state of charge of the battery. These power pulses can be a source of EMI. The PWM controller reduces the voltage from the PV panel so as to match the battery. This voltage drop causes a loss of some of the power available to the battery.

Example

PV Panel	17.6 V at 7.4 A
Power from panel	130 W
If battery is at 12.6 V, then:	
PWM maximum charging amps in system are	7.4 A (panel max)
PWM maximum charging power to battery is	**93** W

MPPT Charge Controller

The Maximum Power Point Tracking controller looks at the PV panel output and battery voltage and continuously selects (tracks) the best voltage so as to maximize charging amps to the battery. The controller is a high frequency dc to dc converter and can be a source of EMI if not suppressed or isolated. It takes the output of the PV panel, changes it to HF ac, runs it through a transformer, then changes it back to a DC voltage that matches the battery.

Example

PV Panel	17.6 V at 7.4 A
Power from Panel	130 W

If battery is at 12.6 V, then:

MPPT maximum charging amps available at battery	10.3 A
MPPT maximum charging power available at battery	**130** W

2) Lead/acid Batteries-

a) Flooded cell — (wet cell) includes many auto batteries (12 V) and golf cart batteries (6 V). User may need to add water and they are characterized by venting of gases. For solar systems, they can give the most power per $, but user must consider hazards involved.

b) Gel Cell — technology is used to gel the electrolyte so as to prevent spillage. However, they must be more slowly charged and use slightly lower recharge voltages to prevent bubbles from forming within the cell. In hot climates, water loss may occur even though they are sealed. Have lost market share to AGM batteries.

c) AGM — absorbed glass mat batteries will take more abuse than gel cell batteries and will not leak even if the case is cracked. Recharging is same as for regular batteries, plus they have low self-discharge rates, low internal resistance when under heavy loads (helps prevent heat build up), and little or no gassing occurs at normal conditions. Costs about the same as a gel cell.

IMPORTANT NOTE — none of the lead/acid type of batteries discussed should be used in enclosed or non-vented areas. Read the manufactures' instructions on the battery case or visit the appropriate web site. Always wear eye protection and gloves when working with lead/acid batteries.

3) Solar Equipment (initial listing)

Solar Panel	Kyocera KC130TM	$484
Solar Mounting Hardware	Ironridge UNI-SP/01XH	107
Charge Controller (PWM)	Xantrex C35 12 V	89
Charge Controller Digital Display	Xantrex CM	73
Battery	Deka 8A4D	331
Disconnect Box	Lowes	40
Data Tracker	Veleman PCS 10	85
Does not include shipping	total	$1209

Charge Controller (PMMT)	BZ MPPT 500	207
Low Voltage Disconnect	Cole Hersee 48513	TBD

4) PV Panel Properties

Kyocera KC130TM

Max Rated Power	130 W
Voltage at Max Power	17.6 V
Current at Max Power	7.4 A
Open Circuit Voltage	21.9 V
Short Circuit Current	8.0 A
Length x Width x Depth (inches)	56.1 × 25.7 × 2.3
Weight (lbs)	26.8
Conversion Efficiency	16%

5) Deka AGM Battery Voltages

Ambient Conditions

State of Charge vs Open Circuit Voltage(OCV)

Deka 8A4D

100%	12.8 V
75	12.6
50	12.3

source -Deka Customer Service, October , 2009

6) Temperature vs voltage (OCV) vs state of charge

Temperature	State of Charge	Voltage
90° F.	100%	12.79
90	75	12.56
90	50	12.31
60	100	12.76
60	75	12.53
60	50	12.28
30	100	12.72
30	75	12.49
30	50	12.24

source www.jgdarden.com/batteryfaq/carfaq4.htm

7) System Sizing Work Sheet

This worksheet was abstracted from the Real Goods Solar Living Sourcebook (30th Edition), John Schaeffer, Editor, and is used by permission.

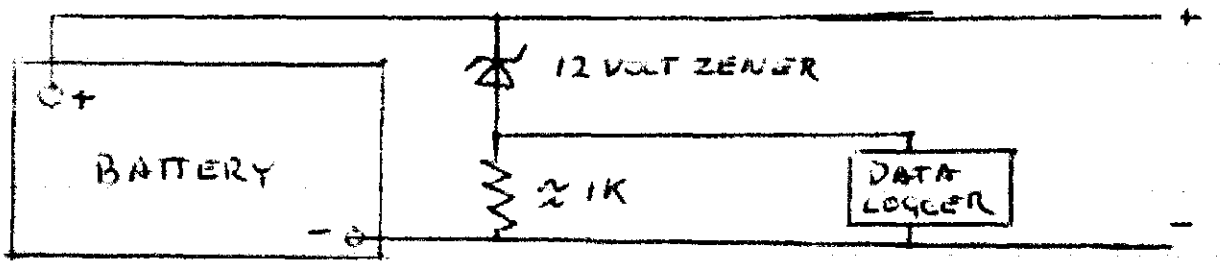
		Transmit	Receive	
Device Watts		60.0	6.0	
Hours per Day		4.0	24	
Days per Week		3.0	7	
Total dc Wh/day	1728			Device watts × Hrs of Day Use × Use per Wk
Average Wh/day	246.9			Total dc watts divided by 7
Battery Voltage		12.0		
Total dc Ah/day	20.6			Ave Watt Hrs per Day Divided by Bat. Volts
Bat. Wiring Losses Safety Factor		24.7		Total dc Ah/day × Safety Factor (1.2)
Hrs. per Day of Sun		4.0		
Total PV Current Needed		6.2		
123 Watt PV Module Amps		5.0		

BATTERY SIZING

Ah (Line 7)	20.6		
Reserve Battery Capacity In Days		5.0	
% of Usable Battery Capacity		0.5	
Minimum Bat. Cap.		205.6	Ah × Reserve Bat Capacity Divided by Usable Capacity

Conclusion: **Need one 8A4D size Battery**

8) Zener Diode Circuit Diagram



Note that the graph in Figure 7 of the QST article has a spread of only 2.2 V on the x-axis. This is because the difference between a fully charged battery and a mostly discharged one is less than three volts and the data from zero to eleven volts are not of interest. To enhance the sensitivity of the graph, we made use of a 12 V zener diode. When used as shown in the above figure, the value of the zener becomes the baseline of the graph (true voltage of the zener was measured at 11.34 V). Only values above this baseline up to full battery charge voltage are plotted, resulting in enhanced graphic sensitivity within the range of interest.

9) Low Voltage Disconnect (LVD)

With the assistance of the Cole Hersee Company, we have recently been working to identify a LVD that could be used to protect our battery should excessive discharging occur. They have programmed their Model 48513 LVD for us based on our operating conditions and in the initial testing, it appears to do a good job. We greatly appreciate their help on this aspect of our project. See www.colehersee.com .

10) Safety
Lead/acid batteries.

None of the batteries discussed in this manuscript should be used in enclosed or non-vented areas. Read the manufacturers' instructions on the battery case or visit the appropriate web site.
Always wear full eye protection, gloves and protective clothing when working with lead/acid batteries. Guard against accidental short circuits and protect exposed battery posts from metal objects.

Electrical

Employ a correctly sized, fused disconnect.
Properly ground your system.
Guard against accidental short circuits and protect exposed battery posts from metal objects.

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