SSP 1020 Demo Board:

The SSP1020 is a highly integrated IC for use in small solar lighting applications The SSP1020 combines LED drive, day/night control, solar panel power conversion, and battery charge logic in single low-cost 8-pin IC. The SSP1020 demo board is intended to demonstrate these capabilities and provide the designer clear examples of how to implement Solar LED lighting products. Figure 1 shows in block form the basic elements of a solar LED lighting application.

1.0 Running the SSP1020 Demo Board:

The SSP1020 demo board is supplied with a 4-cell Lithium battery pack with a nominal capacity of 4.0AH at 12.6V. This battery pack is fitted with a polarized connector. Plug the battery connector into the SSP1020 demo board. The LEDs should immediately light up. Note: the SSP1020 is NOT fitted with a blocking diode so that the system efficiency is as high as possible. Reversing the battery input connections to the SSP1020 will result in damage.

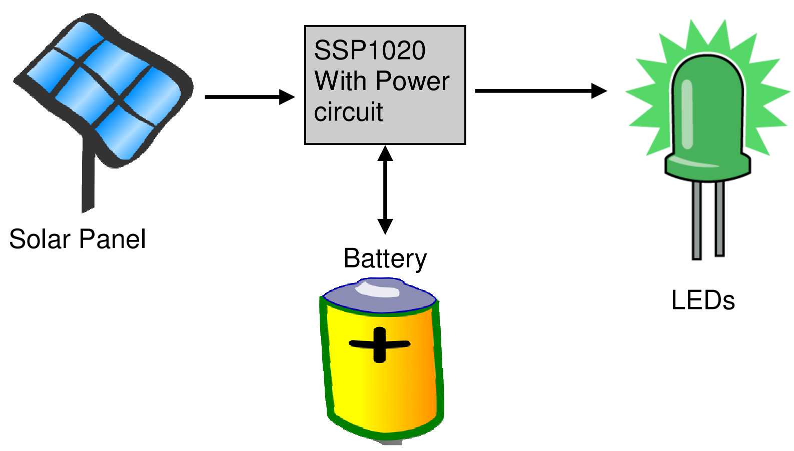


Figure 1, Solar LED Lighting System using SSP1020

The SSP1020 demo board is normally used with any standard type 36-cell solar panel of 10W to 20W rating. Solar panels consist of partial or whole cells which are connected in series. The 36-cell type panels are normally referred to as “12V panels” even though the Maximum Power Point (MPP) is 18.0V. The ability of the SSP1020 to keep the solar panel at 18.0V is a key part of effective energy harvesting.

The solar power input to the SSP1020 is exceptionally stable so an adjustable bench power supply may be used in lieu of a solar panel for purposes of development and test. To use the SSP1020 with a bench power supply follow these steps:

1. Set the output voltage of the power supply for 21V. This will emulate the open circuit voltage of the solar panel. Connect the output leads together. Set the current limit for 1.0A. Turn off the power supply and connect the leads to the Solar Input terminals. Be careful to observe correct polarity.
2. Plug the battery into the Demo Board. The LED should illuminate.
3. Turn on the power supply. The LED should turn off as the SSP has determined that it's daylight.
4. Within 30 seconds the output of the power supply should stabilize at approximately 18V, showing that the solar MPP regulation is working.
5. Turn off the power supply. Within 30 seconds the LED drive will turn back on.
6. When the battery is fully charged the battery voltage will drop from a peak of 16V to approximately 14.7V.
7. The SSP1020 will continuously manage the LED drive, battery charge, and solar input power conversion as needed.

2.0 SSP1020 Pin Descriptions:

#	Name	Type	Description
1	VCC	Power	Positive power supply pin. The voltage on this pin must be equal to or greater than 2.0V The device will continue to run at a voltage as low as 1.8V but the voltage thresholds will not be reliable.
2	FETSLR	OUT	Drive signal for buck mode power FET for solar charge
3	VSLR	IN	Signal to monitor solar panel voltage
4	BATT[5]	IN	Input control for the battery charge mode, low=Pb High = Lithium
5	FETLED	OUT	Drive signal to control FET used in Buck-Boost LED drive. For most applications this signal will not have sufficient to drive the gate terminal of a FET directly
6	ILED	IN	Signal to monitor the drive current of the LED. This signal usually requires a bypass capacitor to suppress noise.
7	VBATT	IN	Input signal used to control the battery charge cycle. A resistor divider is used to divide down the battery voltage to equal the number of cells.
8	GND	Power	Ground pin.

Note 5: Custom Charge available as an OEM option. Call us for more information.

3.0 Using the SSP1020 Inputs:

The SSP1020 has 4 inputs, in addition to power and ground. These inputs are used to control the solar panel, the LEDs, and the battery charge functions. These inputs are designed to accomplish more than one function. For example, the SSP1020 may be used as a cost effective and efficient LED driver without a solar panel and the sola input can be used to enable/disable the LED output. For a listing of the SSP1020 pin assignments, see the SSP1020 Datasheet.

3.1 Power Supply (VDD):

Power is supplied to the SSP1020 on the VDD pin (pin 1) and the GND pin (pin 8). For maximum and minimum input voltage please see the SSP1020 datasheet. The various analog functions in the SSP1020 are fully qualified to work at VDD input as low as 3.3V. The SSP1020 will function at VDD as low as 2.0V but the accuracy of the battery charge and the input MPP control of the solar panel has not been verified as of the date of this document. If your application requires continuous operation less than 3.3V please contact Sensible Solar Power for more operation. The design examples shown in this document assume a VDD value of 5.0V. *If a VDD of less than 5.0V is used, then the reference voltages shown in the datasheet will be reduces as a ratio of the actual VDD to 5.0V*

3.2 VSLR (Pin 2):

The VSLR input is used to monitor the output voltage of the solar panel. Regulating the output voltage of the solar panel is an important feature of Maximum Power Point (MPP) control. The SSP1020 will attempt to regulate the solar panel output so that the voltage present on the VSLR pin is 3.25V. As an example, consider the input voltage divider shown in Figure 2. If we use a solar panel with the MPP voltage of 18.0V, then the divider ratio would then be 3.25 / 18.0 = 0.180. Setting R1=100K and solving for R2, R2 = 22K.

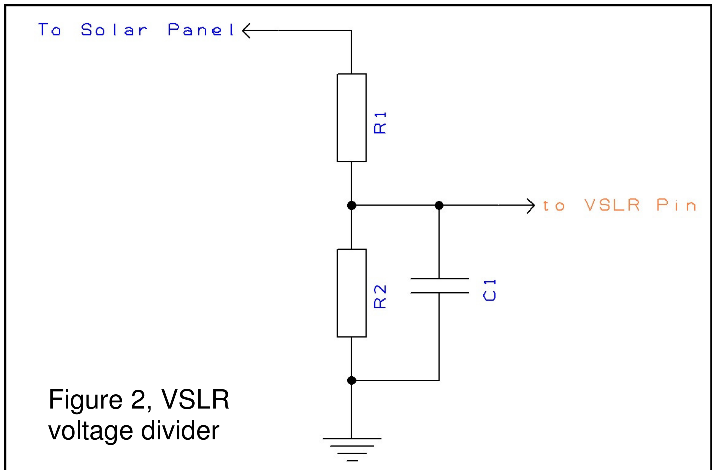


Figure 2, VSLR voltage divider

This technique allows 9V (18 cell) and 24V (72 cell) panels. C1 is used as a noise filter. A value of 0.1uF is suggested for all applications. The SSP1020 regulates the output of the solar panel by modulating the amount of energy extracted from the solar panel. Extracting a larger amount of energy will cause the voltage to go down, and vice-versa

3.3 BATT (Pin 3):

The BATT input is used to change the battery charge cycle to conform to the battery chemistry used in the application. As of the date of this document lead-acid (gel-cell or AGM) and Lithium are the only supported types. Contact SSP if your application requires use of NiMH type batteries. The Lithium battery type is selected when BATT pin is free floating or connected to VDD. Lead-acid is selected when the BATT pin is connected to GND. Note: This pin has an internal pull-up resistor of approximately 100K.

3.4 ILED (Pin 5):

The ILED input is used to program the LED current on a cycle-by-cycle basis. The SSP1020 uses this current signal to set the on time of the LED driver switch. The off time is fixed. The SSP1020 can support either buck or buck-boost type output topologies. Figure 3 shows a typical circuit to used to generate the current ramp. A 170mV internal reference is compared to the ramp. When the voltage on this pin exceeds 170mV the LED is turned off. The resistor R1 is used to set the desired LED current. The value of R1 is: LED current = 0.170 / R. For example, if an LED current of 0.35A is needed then R = 0.49 Ohm. Switching circuits are noisy. Noise is generated when the output FET turns off and on and when steering diodes turn off and on. R2 and C1 in Figure 3 are used to suppress noise, if needed. Starting values of 1.0K for R2 and 47pF for C1 are suggested.

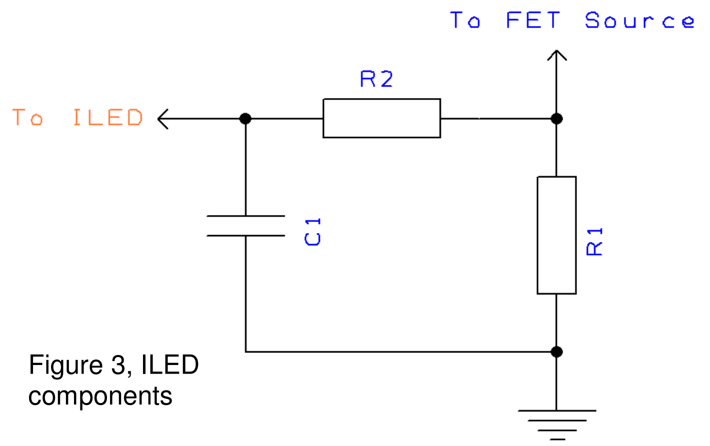


Figure 3, ILED components

3.5 VBATT (Pin 6):

The SSP1020 can support either Lead-Acid or Lithium type batteries. Manufacturers of batteries produce datasheets which describe the behavior of the batteries in both charge and discharge modes. Batteries which consist of individual battery cells are typically assembled in packs. For example, the battery pack included with the SSP1020 demo board is 4 each of 3.2V Lithium battery cells connected in series for a total of 12.8V. A 12V lead-acid battery consists of 6 each of 2.2V cells connected in series for a total of 13.2V. To simplify the validation of your design the voltage on the VBATT pin is compared to an internal reference which is set depending on the state of the BATT select pin. The divider ratio of R2 and R1 should therefore divide the total number of cells down to the value of 1 cell. For example, if 4 cells are used the divider ratio should be 1/4. This technique was chosen so the value on the VBATT pin can be easily verified against the manufacturer datasheet. For example, if the manufacturer specifies a charge cutoff value of 4.00V per cell and 4 cells are used, then use a divider ratio of 1:4 so that the battery pack will stop charging when the entire battery pack reaches 16.0V

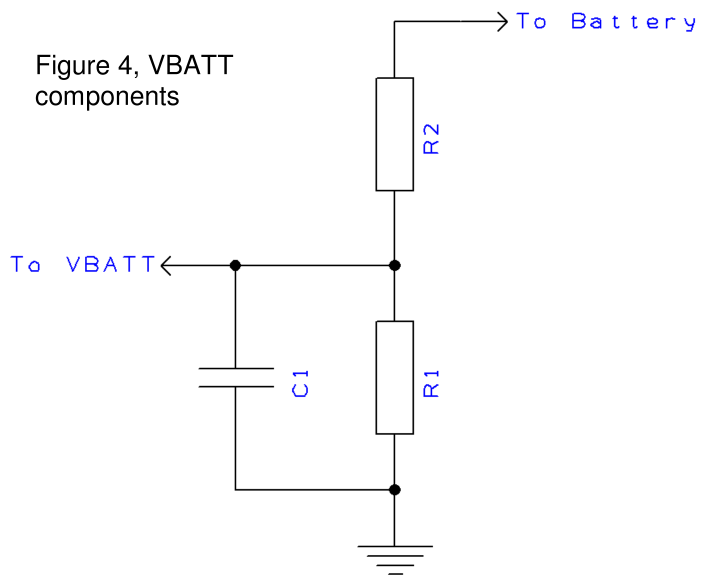


Figure 4, VBATT components

4.0 Using the SSP1020 Outputs:

The SSP1020 has 2 inputs, one for the control of the LED drive FET and another for the control of the solar power converter FET. Both of these outputs are limited to a sink and source current of 5ma so buffer is required for most applications.

4.1 FET drive buffers:

SSP recommends limiting the gate capacitance charge and discharge time to not more than 5% of the switching time. For example, the LED drive section of the SSP1020 has a maximum switching frequency of 150KHz, which corresponds to a switching period of 6.7uS. The gate charge delay of the switching FET should be not more than 5% of 6.7uS or 333nS. The SSP1020 Demo Board uses an FDC637 FET, with a gate charge of 12nC. To meet the 5% requirement a minimum of 12nC/333nS = 36mA is required. Two each of a good CMOS buffer, such as a 74LVC2G17, or a small bipolar emitter follower, would work well in this application.

4.2 LED Output Drive, FETLED (pin 5):

A detailed description of the LED drive cycle can be found in the SSP1020 Datasheet. Selection of the components used in the LED drive starts with the value of inductor L1, as shown in Figure 5. It is advantageous to have continuous current flowing through the LEDs D1 and D2. Start with a target value of the current decreasing by 30% during the off time. Using the fixed off period of 4uS and an average current of 0.35A, the following values are used: Vbatt = 15V, Toff = 4uS, di = 30% of 0.35 = 0.105A, L= 15*(4uS/0.105) = 600uH. A 560uH value will work well, such as Bourns SDR1006-561KL. Increasing the LED current to 0.7A would allow the value of L1 to be reduced by 1/2. SSP recommends that the

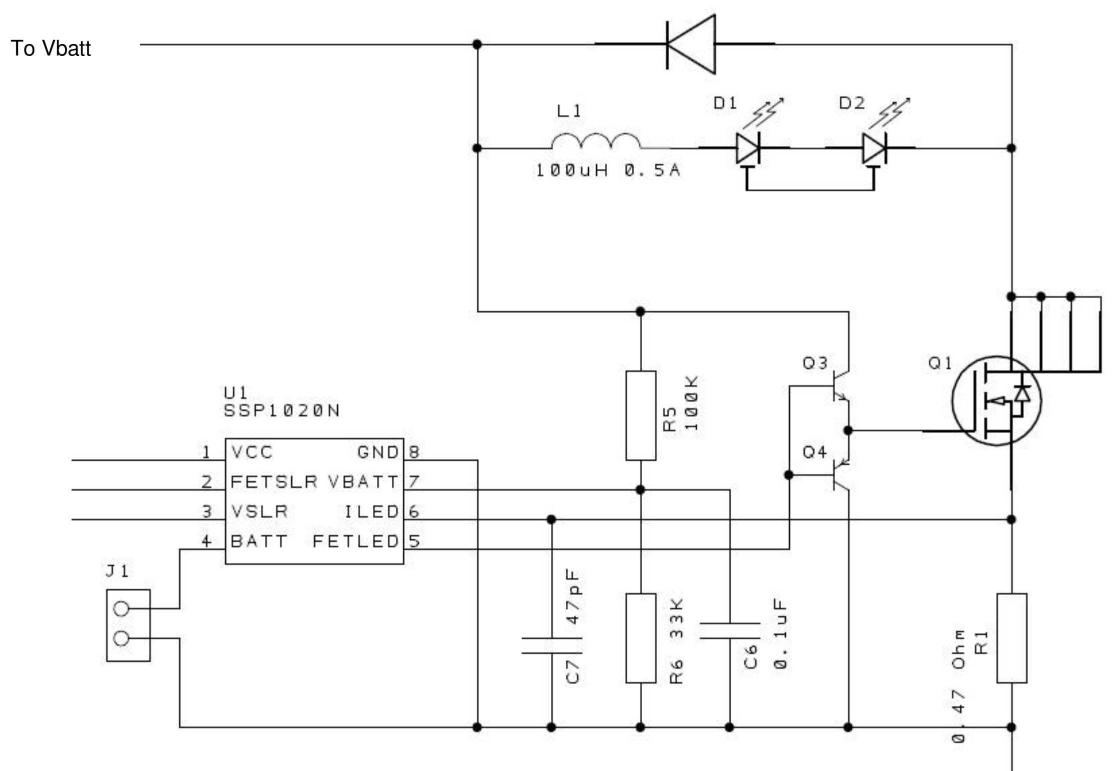


Figure 5, LED Drive

DC resistance of the inductor times the square of the average LED current should be no more than 5% of the total output power, or less for systems where efficiency is a higher priority than cost.

4.3 Solar Output Drive, FETSLR (pin 2):

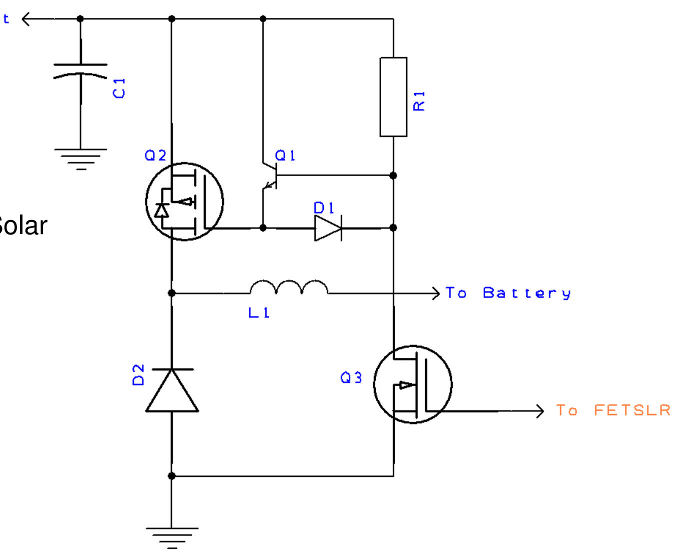


Figure 6, Solar Converter

A detailed description of the logic controlling the MPP solar converter can be found in the SSP1020 Datasheet. An example of power circuit is shown in Figure 6. Component selection begins with the value of L1. The function of the solar converter is very different than the LED driver. The solar converter relies on the limited current of the solar input to establish the operating point of the solar panel. The converter runs at a fixed frequency of 80KHz and the on-time is modulated to maintain a constant input voltage equal to the MPP of the solar panel. The MPP operating point is set by the VSLR input pin (pin2). When the input voltage at the VSLR pin is less than the reference value of 3.25V the on-time is decreased. If the input voltage is greater than 3.25V the on-time is increased. SSP recommends selecting a value of L1 so that the ripple current is approximately 33% of the average input current. The current in L1 will decrease when Q2 turns off. The maximum decrease in current will occur when the off time is greatest, which occurs when the battery voltage is lowest:

Assume the following conditions:
Psolar = 20W, Vmpp=18.0V, Impp=1.11A

Vout=(Ton/Tpwm)*Vin, therefore Ton=Tpwm*(Vout/Vin)

Ton = Tpwm-Toff, thus Toff=(1-(Vout/Vin))*Tpwm

Use a worst case value of Vbatt=10V at low cutoff, and assume that Vsolar=18V. Toff will then be (1-(10/18))*1/80000 = 5.6uS

L = (Vin-Vout)(Toff/30%*Impp)
L = 135uH, use 150uH

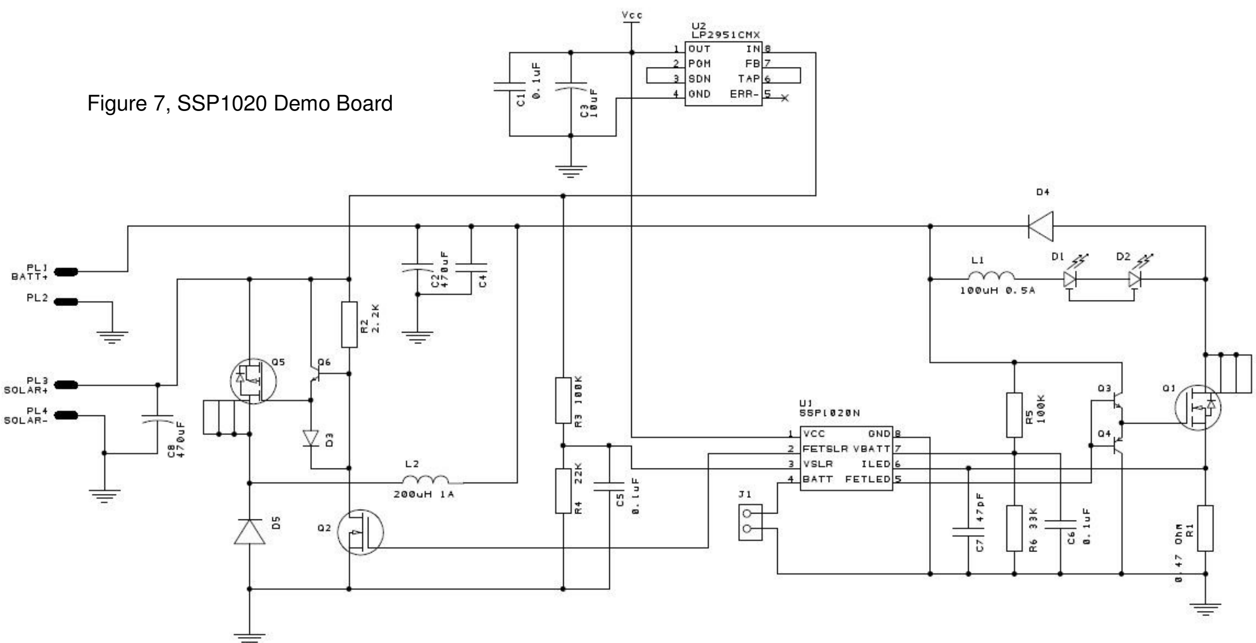
Note that the storage capacitor C1 will be charged by the solar panel during the off time of Q2. When Q2 turns off the solar panel should be operating at or near its MPP current (Impp). The ripple current in C1 will therefore equal to the solar panel output current at MPP. Aluminum Electrolytic capacitors are commonly used in this application so the designer should exercise care when selecting this part. Most Aluminum Electrolytic caps are rated for their maximum ripple current for only 2000 hours. The capacitors should be selected for adequate service life at their rated current. Drive transistor Q3 doubles as a driver for Q2 and a level shifter. Q3 is a sink for the gate capacitance of Q2. The gate of Q2 is pulled-up by NPN transistor Q1. Consult SSP for more information regarding MOSFET gate drive

5.0 SSP1010 Demo Board

Figure 13 shows the complete schematic of the SSP1020 Demo Board. This demo board implements a complete high performance, low cost solar LED lighting system with the following characteristics:

- 15W solar panel input (solar panel not included).
- 48 Watt-Hours of energy storage using 4 each of 4AH Lithium batteries (included).
- Up to 480 Lumens of LED output using 2 each of Philips LXML-PWN1 LEDs
- LED optics and heat sink included
- Very high efficiency
- Low cost
- Easy to use
- Readily available

Figure 7, SSP1020 Demo Board



SSP Demo Board, Bill of Material

Component	Value	Manuf	Manuf Part No	Distributor	Ref Name	Qty	Note: suggested component source is
CAP, Al Elect 10mm	470uF	NIC	NACZ471M25V10X10.5TR13F	Future	C2 C8	2	
CAP, 0805 Size	0.1uF	Any		Future	C1 C5 C6	3	
CAP, SMA Size	10uf	Nichicon	F920J106MPA	Future	C4	1	
CAP, 0805 Size	47pF	Any		Future	C7	1	
CAP, SMA	10uF	Nichicon	F920J106MPA	Future	C3	1	
DIO SMA	30V 3A	On Semi	B340-13-F	Future	D4,5	2	
DIO, SOD-123	60V 0.25A	Diodes Inc	1N4148W	Future	D3	1	
DIO, LED LXM2	240 LM	Philips	LXML-PWN1-0070	Future	D2 D1	2	
HDW, Keystone 8730		Keystone	8730	Future	PL1-4	4	
IC, LP2951CD_2	5V Out	Fairchild	LP2951CMX	Future	U2	1	
IC, SSP1020		SSP	SSP1020N	Future	U1	1	
IND, 7mm x 7mm	100uH 0.5A	TDK	SLF7045T-101MR50-PF	Future	L1	1	
IND, 10mm x 12mm	200uH 1A	NIC	NPI34W221MTRF	Future	L2	1	
RES, 0805	2.2K	Any			R2	1	
RES, 0805	22K	Any			R4	1	
RES, 0805	33K	Any			R6	1	
RES, 0805	100K	Any			R3 R5	2	
RES, 1206	0.47 Ohm	Susumu	RL1632R-R470-F	Future	R1	1	
XTR, NFET SOT23	60V 0.25A	On Semi	2N7002ET1G	Future	Q2	1	
XTR, NFET SOT23-6	30V 50m	Fairchild	FDC655BN	Future	Q1	1	
XTR, NPN SOT23	60V 0.5A	On Semi	MMBTA05LT1G	Future	Q3 Q6	2	
XTR, FET SOT23-6	30V 75M	Fairchild	FDC654P	Future	Q5	1	
XTR, PNP SOT23	60V 0.5A	On Semi	MMBTA55LT1G	Future	Q4	1	

Note: These components are available from www.futureelectronics.com

6.0 Energy Budget

The SSP1020 is a complete, stand alone controller which manages the flow of energy from the solar panel into the batteries, then from the batteries into the LEDs. Solar products are successful when reliable performance is delivered in a cost-effective way. The best way to ensure performance and control cost of a solar system is to effectively match the size of the batteries and the solar panel to the requirement of the load. For best performance SSP suggests this procedure:

1. Determine the power needed for the LEDs. The LEDs in the SSP1020 Demo Board are set to produce 1.0W each, 2.0W total. The SSP1020 by default runs the LEDs at night. The day/night operation of the SSP1020 can be overridden, but the default behavior of the internal circuitry is to run the LEDs for approximately 12 hours. This is a total energy requirement of 24WH watt-hours per day, because the 2W load will run (by default) for about 12 hours.
2. Select the correct size of solar panel. The amount of solar energy harvested per day should be greater than the amount needed for the LEDs (or any other load) to allow for bad weather. SSP is located in Palmdale, CA which receives (on average) 6.3 hours per day. This average is a weighted average, meaning an average of 6.3 total hours of “full direct” sunlight. The actual illumination changes throughout the day. For example, in the winter at 8:00AM there may only be 5% of full sunlight available, the 12% at 9:00AM, and so on. A map of the average available amount of sunlight can be found at http://www.nrel.gov/gis/solar.html . SSP suggests a safety margin of 2-3 times the amount of use. For cost sensitive applications this safety margin can be achieved by limiting the energy use during intervals when energy harvesting is poor. Contact SSP for more information. Using a 2x safety margin, if 24WH per night is needed for the LEDs then a minimum of 48WH of energy production should be used. This 48WH will be harvested, on average, in a period of 6.3 hours which suggests a solar panel size of 48/6.3 = 7.6W. A 10W panel is a common size which should perform well.
3. The batteries should be able to support the load through the night. The batteries will also have to support the load when the solar input is diminished, for example in bad weather. Please note that when the sky is overcast but there is no precipitation the amount of solar energy will still be in the range of 30% to 60% of full sunlight. The amount of energy storage in addition to daily use is a specification which requires careful attention to the intended use. For example, the MUTCD specifications for solar arrow boards call for a minimum of 30 days operation without solar input. A common standard for solar sign lights is to provide full output for 3 days of 12 hours per day with no solar input. The SSP1020 demo board is supplied with a 48WH battery pack which is sufficient to power the 2W LED output for 2 days.

7.0 SSP1020 User's Guide Revision History

Revision	Date	Description
A0	10/01/2010	Initial Release
A1	10/18/2010	Spelling corrections