cap-XX

PC Card Extender and Supercapacitor Evaluation Board

Part No. APPEB1003

User's Manual

Revision 1.0
February, 2003

Evaluation Board Features

- PC Card Extender
- Supercapacitor (two form factors)
- Adjustable current limit circuit with Supercapacitor charge enable
- 3.3V and 5V input LEDs
- Supercapacitor voltage comparator with adjustable threshold, adjustable hysteresis and Power Good LED
- Card Detect switches to simulate card removal and insertion
- Sub-circuits can be disconnected to reduce the load
- Test points, jumpers and I/O connectors

Typical Supercapacitor Applications

- PC Card
- Compact Flash
- PDA
- Smartphone
- GPRS
- Handheld Equipment
- Load Leveling

Contents

1.0 Introduction

This User's Manual is for the cap-XX PC Card Extender and Supercapacitor Evaluation Board (Part No. APPEB1003). This board was designed for the evaluation of a supercapacitor in a PC Card. The application of supercapacitors is limited only by the user's imagination. Typical examples are PC Card, Compact Flash, PDA, Smartphone, GPRS and other handheld equipment.

The Evaluation Board is basically a PC Card Extender with a supercapacitor and a current limit circuit.

An excellent source for information on Supercapacitors and free downloads are available on the cap-XX website at www.cap-xx.com.

In the following description of operation it may be helpful to refer to the Evaluation Board Schematic in the Appendix.

2.0 Input Voltage

The supercapacitors for the Evaluation Board are rated at 4.5V and therefore it is not recommended that the input voltage (V_{CC}) be greater than 4.5V. If V_{CC} is 5V then the Equivalent Series Resistance rise rate of the supercapacitor is increased and the lifetime will be reduced. A red LED is included to indicate that V_{CC} is too high and it starts to glow when V_{CC} is approximately 4.2V. The red LED is labeled on the Evaluation Board as "5 Volts". If V_{CC} is 5V then the voltage can be dropped to < 4.5V by including an external series diode in the voltage supply lines on the Evaluation Board (see section 7.0). A yellow LED is included to indicate when V_{CC} is 3.3V or greater. It is labeled on the Evaluation Board as "3.3 Volts".

If V_{CC} is disconnected (or if the Evaluation Board is removed from the host) and there is still charge on the supercapacitor then current will flow through the body diode of M1 and through the yellow LED (also through the red LED if the supercapacitor is greater than ~ 4.2V). The intensity of the yellow LED then gives an indication of the voltage remaining on the supercapacitor. If, however, external series diodes have been included to reduce the 5V rail to 4.5V then the LEDs will not be ON when V_{CC} is disconnected.

2.1 Charge Time

A fully discharged supercapacitor will be charged to V_{CC} after a certain time (t_c). This time will depend on the current limit (I_L), V_{CC} and the capacitance (C). The equation is

$$t_c = \frac{CV_{CC}}{I_L} \qquad (1)$$

3.0 Current Limit

Circuits that employ large capacitors generally need a current limiting circuit to alleviate the current in-rush problem. The PC Card specification states that for 3.3V the peak current is 1000mA and the average current is 750mA. For 5V the peak current is 660mA and the average current is 500mA. Therefore the peak power from either the 3.3V rail or the 5V rail is 3.3W and the average power is 2.5W. The Evaluation Board has an adjustable current limit circuit. The current limit can be adjusted from 0A to ~ 4.5A by using the potentiometer R2. It is labeled on the Evaluation Board as "Current Limit". Turning the potentiometer clockwise will increase the current limit.

The MOSFET (M1) and Sense Resistor (R1) can withstand up to 4.5A whilst the supercapacitor is being charged. They cannot however withstand the 4.5A indefinitely. Also, there is no short circuit protection. The MOSFET (M1) has a maximum average power dissipation of 2.5W. Therefore any continuous load resistance (R_L) has a minimum value as given by equation 2.

$$R_L > \frac{V_{CC} I_L - 2.5}{I_L^2} \qquad (2)$$

4.0 Enable

The current limit circuit has an enable feature. *Enable* is an active low signal and the two pin jumper is labeled on the Evaluation Board as "J_ENABLE". It is an input signal to the Evaluation Board and it can be jumpered to ground, to be permanently enabled, or it can be externally driven by an open collector or drain. When "J_ENABLE" is externally driven it allows the supercapacitor to be charged only when the User's Card is ready. Pin 2 of "J_ENABLE" is the control input and Pin 1 is permanently connected to ground.

5.0 Power Good

The Power Good circuit (PGOOD) is included to indicate when the supercapacitor is charged to the appropriate level. The voltage on the supercapacitor is compared to a reference using a comparator with adjustable thresholds and hysteresis. The thresholds need to be adjustable on an Evaluation Board because different applications will require different load voltages. The hysteresis also needs to be adjustable because a step in load current will cause a step voltage on the supercapacitor because of the supercapacitor's Equivalent Series Resistance (ESR). Since this step voltage (part of the ripple) is a normal occurrence, it would not be desirable for this to indicate that the supercapacitor is undercharged.

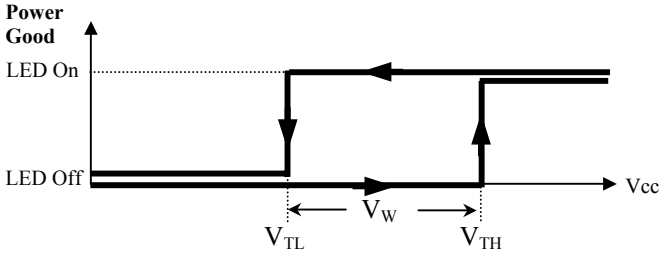


Figure 1 Power Good Hysteresis

As in Figure 1, the high threshold (V_{TH}) is the voltage at which the supercapacitor's unloaded voltage becomes acceptable. The hysteresis (V_W) is the voltage that when subtracted from the high threshold gives the low threshold (V_{TL}). It indicates that the supercapacitor is undercharged. V_{TH} is set by the factory at 3.2V and V_W is set at 0.3V, therefore V_{TL} is 2.9V.

PGOOD has a header labeled on the Evaluation Board as "H_PGOOD". It is an active high output signal that can be used to signal an external circuit that the supercapacitor is fully charged. A green LED is also included to indicate this condition. It is labeled on the Evaluation Board as "Power Good".

6.0 Adjusting the Circuit

Equipment needed: *Adjustable power supply, multi-meter and various power resistors*

Warning: *Be careful not to exceed the supercapacitor rated voltage (4.5V) or the maximum average power rating for M1 (2.5W)*

Sections 6.1, 6.2 and 6.3 explain how to adjust the circuit practically and section 6.4 gives the theoretical equations.

(a) Connect a load power resistor (R_L) of around 10Ω from "VCC_OUT" to "GND_OUT" on "CON_CAPXX". This ensures that the supercapacitor voltage will change in reasonable time when the power supply voltage is changed. Note the power rating of R_L has to be a minimum value according to equation 3.

$$P_{R_L} > \frac{VCC\_OUT^2}{R_L} \qquad (3)$$

(b) Ensure the following jumpers are fitted; "J_RED&YLW", "J_GREEN", "J_PGOOD", "J_ENABLE", "J_VCC17_IN" (pins 3 and 4), "J_VCC51_IN" (pins 3 and 4), "J_VPP18" and "J_VPP52" .

(c) Turn the "Current Limit" - R_2 fully clockwise (maximum current).

(d) Turn the "PGOOD Reference" - R_{15} to around mid position (about 11 turns from either limit).

6.1 Adjusting Hysteresis Width with "PGOOD Feedback" - R_{23}

NOTE: *V_W is adjusted before V_{TH} because the V_{TH} adjustment is affected by V_W. Therefore if adjustments are made in this section then section 6.2 should be checked.*

(a) Decide the high threshold voltage V_{TH} , the low threshold voltage V_{TL} and the hysteresis voltage width V_W ($V_w = V_{TH} - V_{TL}$). V_{TL} has to be greater than the minimum voltage required by the Pulsed Load. V_W has to be greater than the expected voltage droop due to the ESR and capacitor discharge etc.

(b) Set the power supply voltage to say 3.3VDC. Ensure that the power supply can supply the desired current. Connect its negative lead to J_GND1 or J_GND2. Connect the positive lead to pin 1 of J_VCC17_IN or J_VCC51_IN. The LED labeled "3.3 Volts" should now be ON and the LED labeled "Power Good" should also be ON. If "Power Good" is not ON, then turn "PGOOD Reference" - R_{15} anticlockwise slowly until the "Power Good" LED is ON.

(c) Connect a voltmeter across the supercapacitor, which is also across R_L and "CON_CAPXX" (V_{R_L}). Slowly reduce the power supply voltage and note V_{R_L} when the "Power Good" LED turns OFF. Slowly increase the power supply voltage and note V_{R_L} when the "Power Good" LED turns ON. The difference between the two readings is the hysteresis voltage width V_w.

(d) Adjust "PGOOD Feedback" - R_{23} (anti-clockwise increases V_w) and repeat (c) above until precisely the desired hysteresis width is achieved.

6.2 Adjusting the High Threshold with "PGOOD Reference" - R_{15}

(a) Turn "PGOOD Reference" - R15 fully clockwise and then reduce the power supply voltage until the "Power Good" LED is OFF.

(b) Adjust the power supply voltage so V_{R_L} equals the desired V_{TH}. Turn "PGOOD Reference" - R15 slowly anti-clockwise until the "Power Good" LED turns ON.

(c) Check that the "Power Good" LED turns ON and OFF at the desired levels. This can be done by varying the power supply voltage in both directions so that V_{R_L} is less than V_{TL} and then greater than V_{TH}.

(d) Remove R_L.

6.3 Adjusting the Current Limit with "Current Limit" - R_2
Warning: *the maximum average power rating for M1 is 2.5W (see section 3.0)*

(a) Connect a load resistor to "CON_CAPXX" (R_L) that draws just over the desired current limit from the PC Card host. Note the power rating of the resistor is according to equation 3 and R_L has to be a minimum value according to equation 2. For example if the supply voltage is 3.3V and the desired current limit is 1A then an R_L < 3.3 Ω would draw more than 1A. According to equation 2, R_L also has to be > 800mΩ. Choose say 2.7Ω (next standard value < 3.3 Ω) and equation 3 says the power rating must be greater than 4W.

(b) With an ammeter in series with the power supply, adjust "Current Limit" - R2 until the current is limited to the desired value (clockwise increases the current).

(c) Remove the load.

6.4 Replacing the Potentiometers with Fixed Resistors
The potentiometers on the Evaluation Board are included to provide flexibility in evaluating many different applications. In a final design for production the resistance of the potentiometers would have been decided and therefore they can be replaced with fixed resistors. This section includes the equations that can be used to theoretically determine the value of these resistors. The value of these resistors can also be found practically by measuring the resistance of the potentiometers out of circuit once the circuit has been successfully adjusted as above.

$$R22 + R23 = \frac{55k}{V_W} \quad (4)$$

$$R15 + R16 = \frac{4k7V_{TH}}{5 + V_W - V_{TH}} \quad (5)$$

$$R2 = \frac{22k}{\frac{56}{I_L} - 1} \quad (6)$$

6.5 Limits of Adjustment

From the schematic in the Appendix it can be seen that;

R22=100kΩ
R23=500kΩ potentiometer
R15=5kΩ potentiometer
R16=3k9Ω
R2= 2kΩ potentiometer

From equation 4;

$$0.1V \le V_W \le 0.5V$$

From equation 5;

$$2.3V \le V_{TH} \le 3.3V \quad (V_W=0.1V)$$
$$2.4V \le V_{TH} \le 3.5V \quad (V_W=0.3V)$$
$$2.5V \le V_{TH} \le 3.6V \quad (V_W=0.5V)$$

From equation 6;

$$0A \le I_L \le 4.7A$$

If these limits do not suit the application then resistors can be replaced on the Evaluation Board according to equations 4,5 and 6.

7.0 Connecting the Evaluation Board

The evaluation board is inserted into the Host and the PC Card under test is inserted into the Evaluation Board, as shown in figure 2. The supercapacitor terminals are joined to the connector labeled "CON_CAPXX". The terminals of "CON_CAPXX" are labeled "GND_OUT" and "VCC_OUT". These are to be connected as close as possible to the ground and positive supply of the Pulsed Load respectively. For the least voltage droop, it is important to minimise the resistance between the supercapacitor and its load. Therefore the wires from "CON_CAPXX" to the Pulsed Load should be as short and as thick as practical.

Warning: *As stated earlier, if V_{CC} is chosen to be 5V then the voltage at the supercapacitor must be dropped to < 4.5V by including an external series diode. If only one of the two V_{CC} rails is to be used (V_{CC} is on both pins 17 and 51 of the PC Card socket) then the diode can be placed between pins 3 and 4 of the V_{CC} jumper "J_VCC?_IN" (where ? is either 17 or 51). If both the V_{CC} rails are to be used then two diodes should be included. One is placed between pins 3 and 4 of "J_VCC17_IN" and the other between pins 3 and 4 of "J_VCC51_IN". Choose each diode such that the minimum load current (quiescent current) gives an acceptable voltage drop. The minimum load can be adjusted to some extent by the choice of supercapacitor balancing resistors. The PC Card specification states that the 5V rail is ± 5% and therefore the rail may be as high as 5.25V. In this case a voltage drop of 0.75V is required. If the diode does not give enough voltage drop for the minimum current case then two diodes in series may be needed. This is still more economical than using a Low Drop Out (LDO) regulator.*

Note: *The number 1 pin of a header or jumper can be identified on the Evaluation Board as the one with the square solder pad on the bottom layer.*

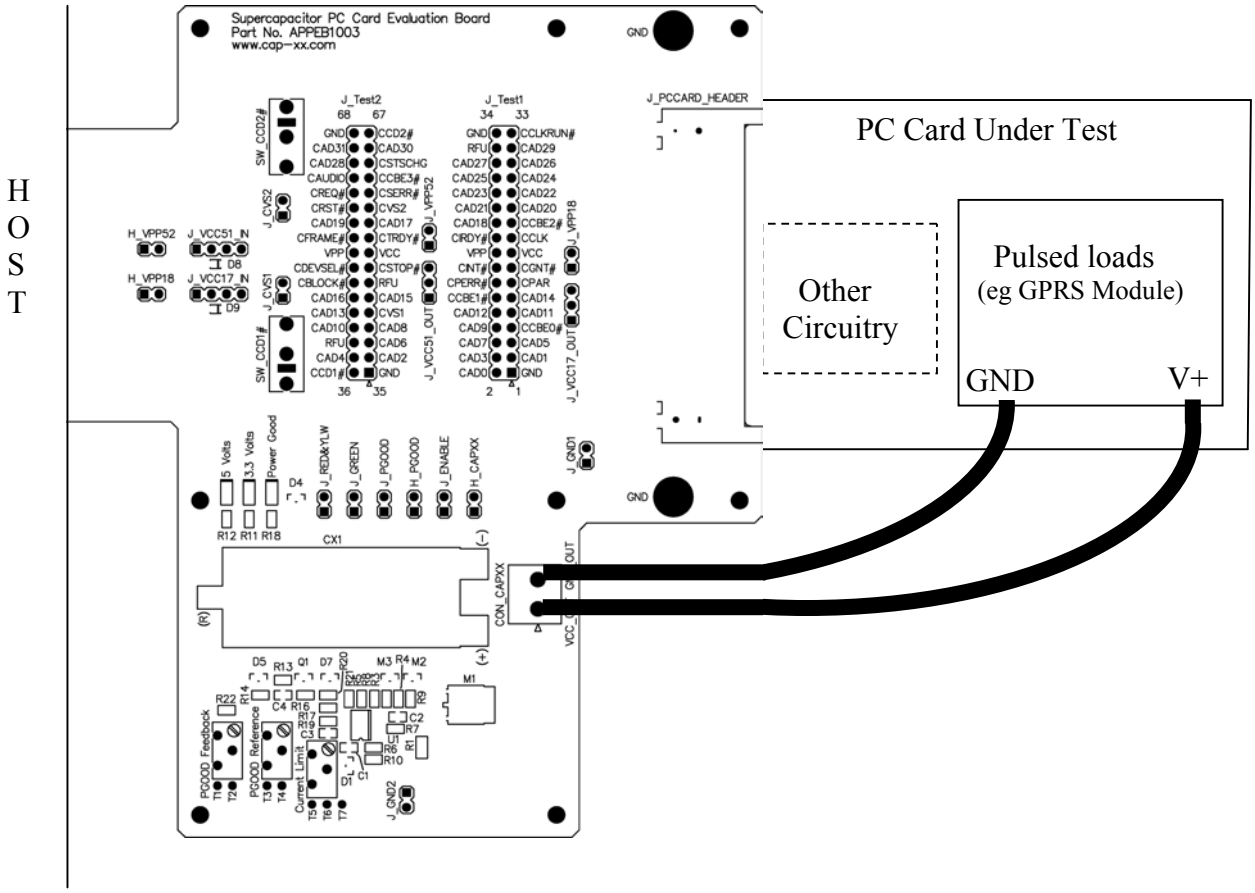


Figure 2 Typical connection of Evaluation Board

7.1 V_{CC} Modes

Figure 2 shows the typical way for connecting the Evaluation Board. V_{CC} on the PC Card Under Test is generally supplied by one of two modes. Mode 1, being the most common, is when V_{CC} is supplied from "J_VCC17_OUT" and/or "J_VCC51_OUT" (via the "J_PCCARD_HEADER" pins 17 and 51). These V_{CC} rails supply all the circuitry on the PC Card Under Test ("Other Circuitry") except for the "Pulsed Loads (V+)", which is supplied by the supercapacitor with the external wires. In this mode V_{CC} is available to the "Other Circuitry" as soon as the PC Card Under Test is powered up, whereas the supercapacitor supply to the "Pulsed Loads" is delayed by the charge up time according to equation 1.

Mode 1 is accomplished by the following;

(a) Remove the jumpers on "J_VCC17_OUT" and "J_VCC51_OUT".

(b) Connect external leads from pin 1 of "J_VCC17_IN" to pin 3 of "J_VCC17_OUT" and from pin 1 of "J_VCC51_IN" to pin 3 of "J_VCC51_OUT".

Mode 2 is when the supercapacitor supplies both the V_{CC} for the PC Card Under Test ("Other Circuitry") as well as the "Pulsed Loads". In this mode all supplies are delayed according to equation 1.

Mode 2 is accomplished by the following;

(a) Place jumpers on pins 1 and 2 of "J_VCC17_OUT" and pins 1 and 2 of "J_VCC51_OUT".

(b) Ensure the external wires are removed from "J_VCC17_IN" to "J_VCC17_OUT" and "J_VCC51_IN" to "J_VCC51_OUT".

Connections common to both Mode 1 and 2 are;

(a) Connect external wires (thick and short) from "CON_CAPXX" to the "Pulsed Loads" on the PC Card Under Test.

(b) Place jumpers on pins 3 and 4 of "J_VCC17_IN" and "J_VCC51_IN". Remember to use the series diodes in place of the jumpers if using the 5V rail.

(c) Place jumpers on pins 1 and 2 of "J_VPP18", "J_VPP52", "J_RED&YLW", "J_ENABLE", "J_PGOOD" and "J_GREEN".

(d) Remove jumpers on "J_CVS1", "J_CVS2", "J_VCC17_OUT" and "J_VCC51_OUT".

NOTE: *Care must be taken, in which ever mode is chosen, so that the charge up time of the supercapacitor does not affect the operation of any reset or power rail monitoring circuitry etc. As described in section 4.0 and 5.0, the "J_ENABLE" and "H_PGOOD" signals may need to be interfaced with the PC Card Under Test for proper control.*

7.2 Current Measurement

The input (Host) current from the V_{CC} rails can be measured with a current probe that is clamped over two external wire loops. One loop is connected between pins 3 and 4 on "J_VCC17_IN" and the other loop between pins 3 and 4 on "J_VCC51_IN". Likewise, the input current from the V_{PP} rails can be measured using two external wire loops between pins 1 and 2 on "J_VPP18" and pins 1 and 2 on "J_VPP52". If a current probe is not available then a sense resistor can be used in place of the wire loops. The voltage dropped across the resistor divided by the value of the resistor equals the current.

7.3 Card Detect

The correct insertion of a PC Card is detected when both pins 36 and 67 are grounded. These pins are typically grounded on the PC Card Under Test. However, the ground signal can also be replicated by using jumpers across pins 35 and 36 on "J_Test2" and pins 67 and 68 on "J_Test2". The removal and insertion of the card can be simulated by depressing and releasing either of the two micro-switches "SW_CCD1" or "SW_CCD2".

7.4 Voltage Select

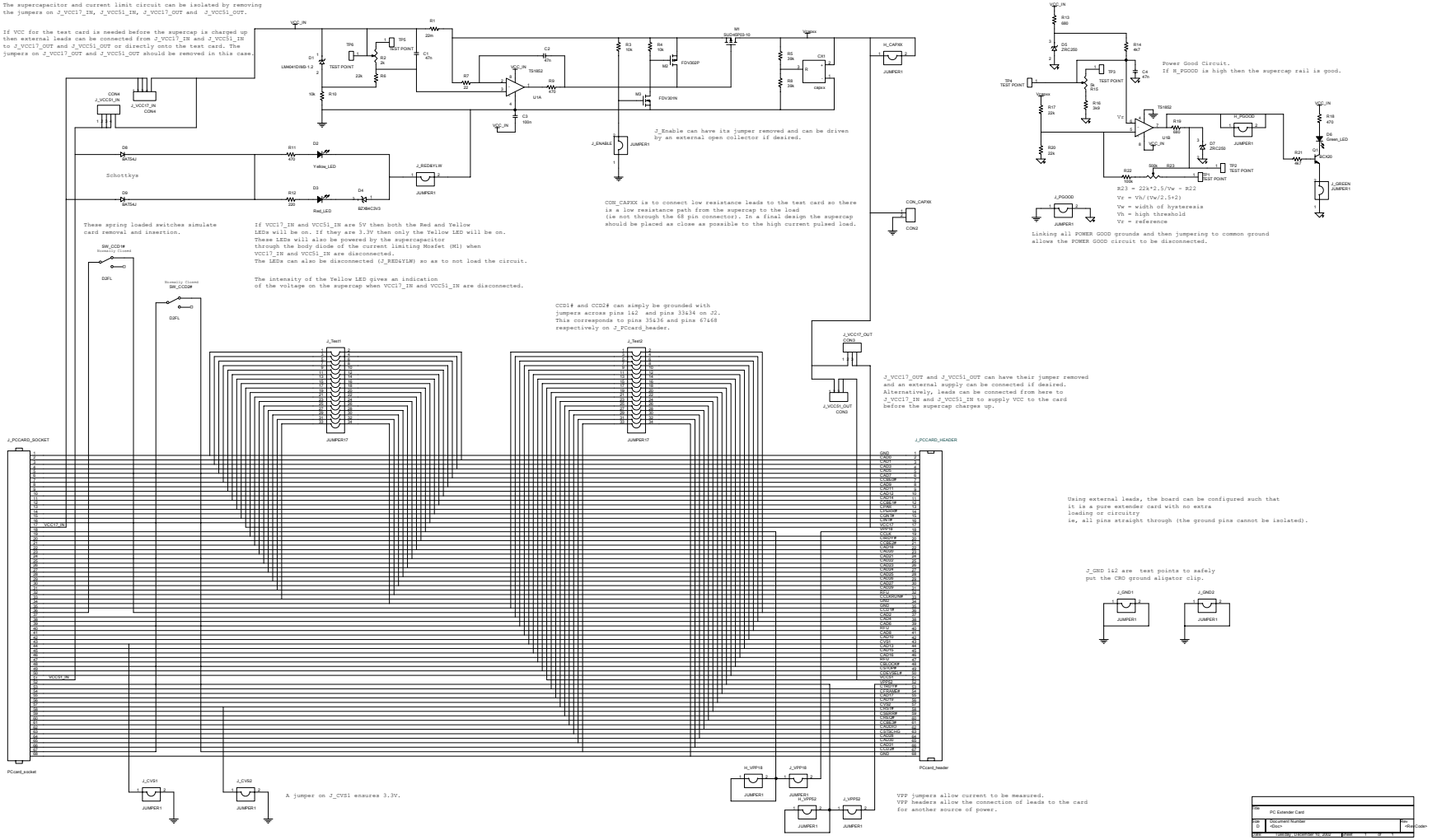
The PC Card Under Test chooses the V_{CC} voltage rail using pin 43 (CVS1). If CVS1 is grounded then a V_{CC} of 3.3V is requested, if it is left floating then 5V is requested. This signal can be replicated with "J_CVS1". Placing a jumper on "J_CVS1" forces the signal to ground and therefore requests 3.3V. "J_CVS2" is undefined and should be left floating.

8.0 Disconnecting Circuits for Reduced Load

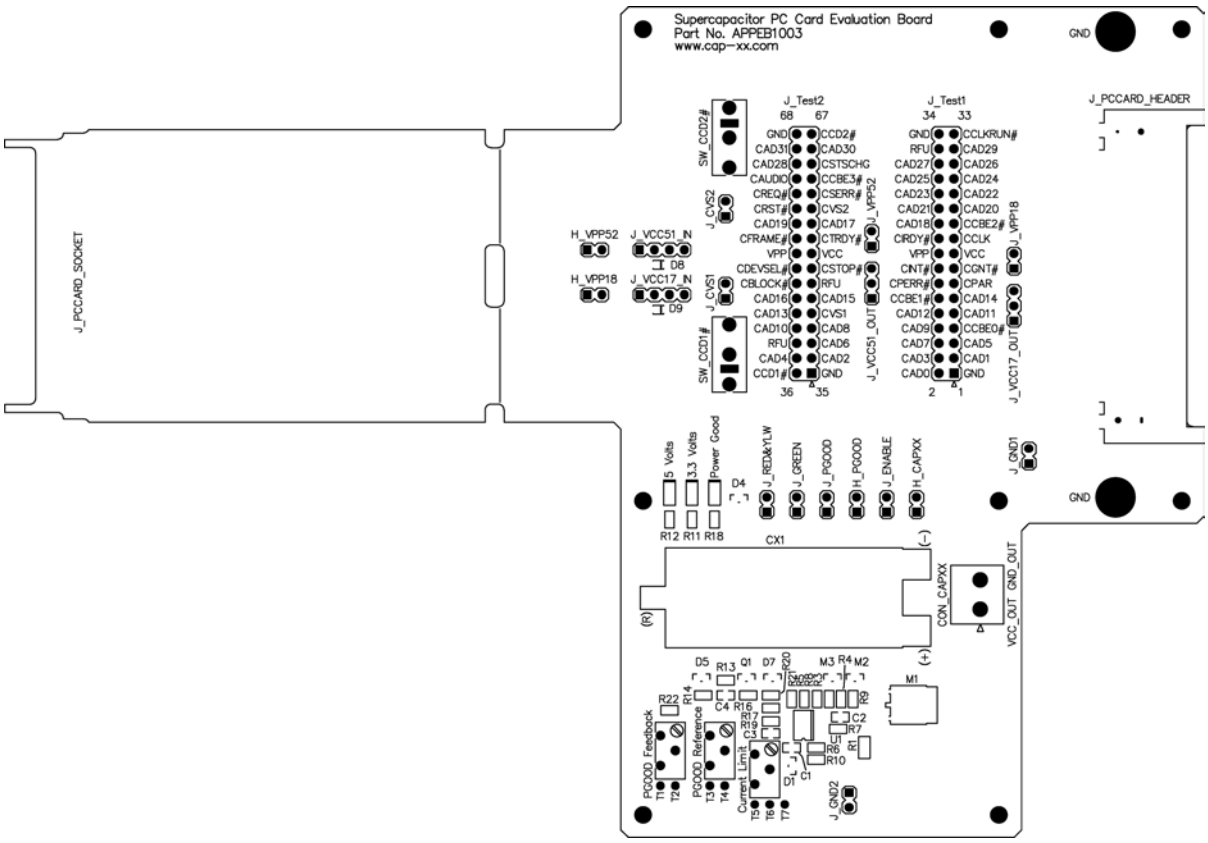
The minimum voltage on some loads may be critical. Any current that the Evaluation Board uses contributes to the droop on the input voltage. If the droop becomes excessive then some of the functions on the Evaluation Board can be disconnected to save current and therefore increase the input voltage. The red and yellow LEDS can be disconnected by removing the jumper "J_RED&YLW". The green LED can be disconnected by removing the jumper "J_GREEN". The entire PGOOD circuit can be disconnected by removing the jumper "J_PGOOD".

Appendix

Schematic



PCB Top Overlay



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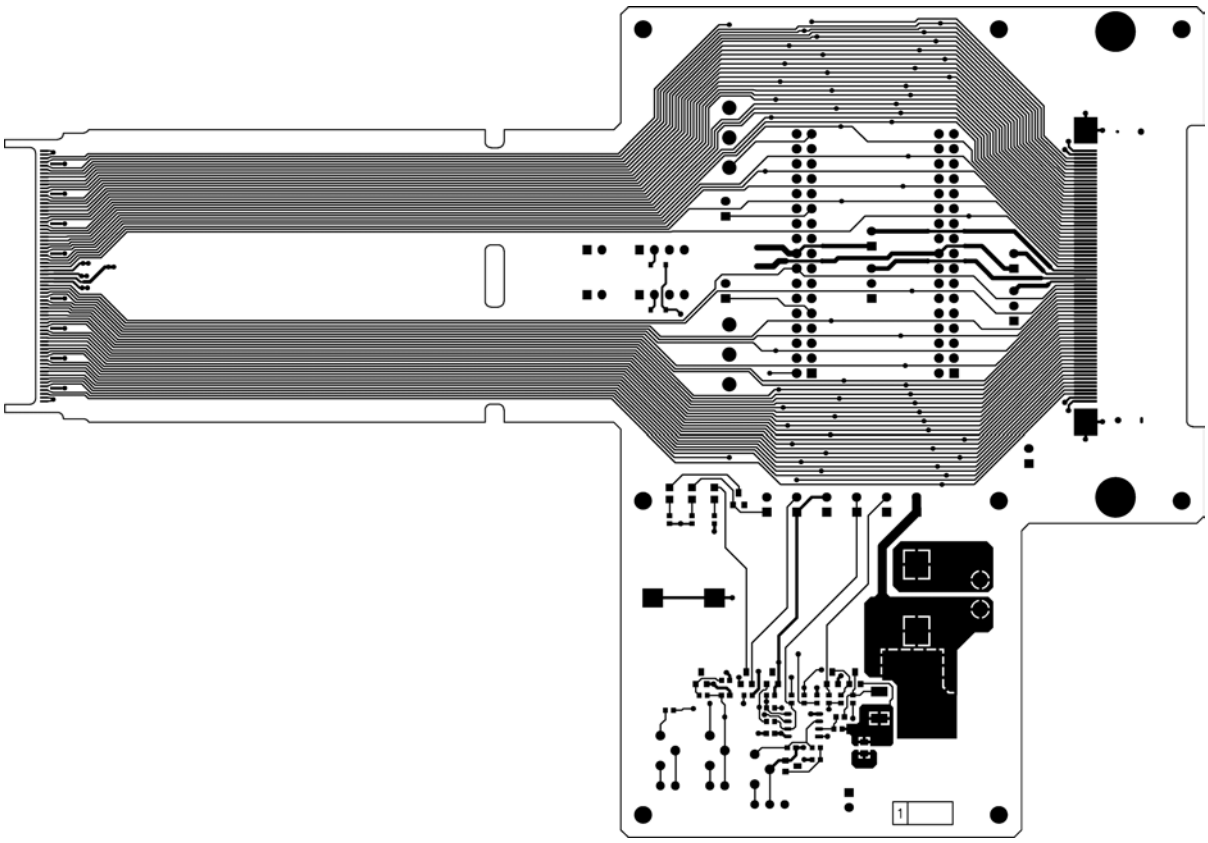

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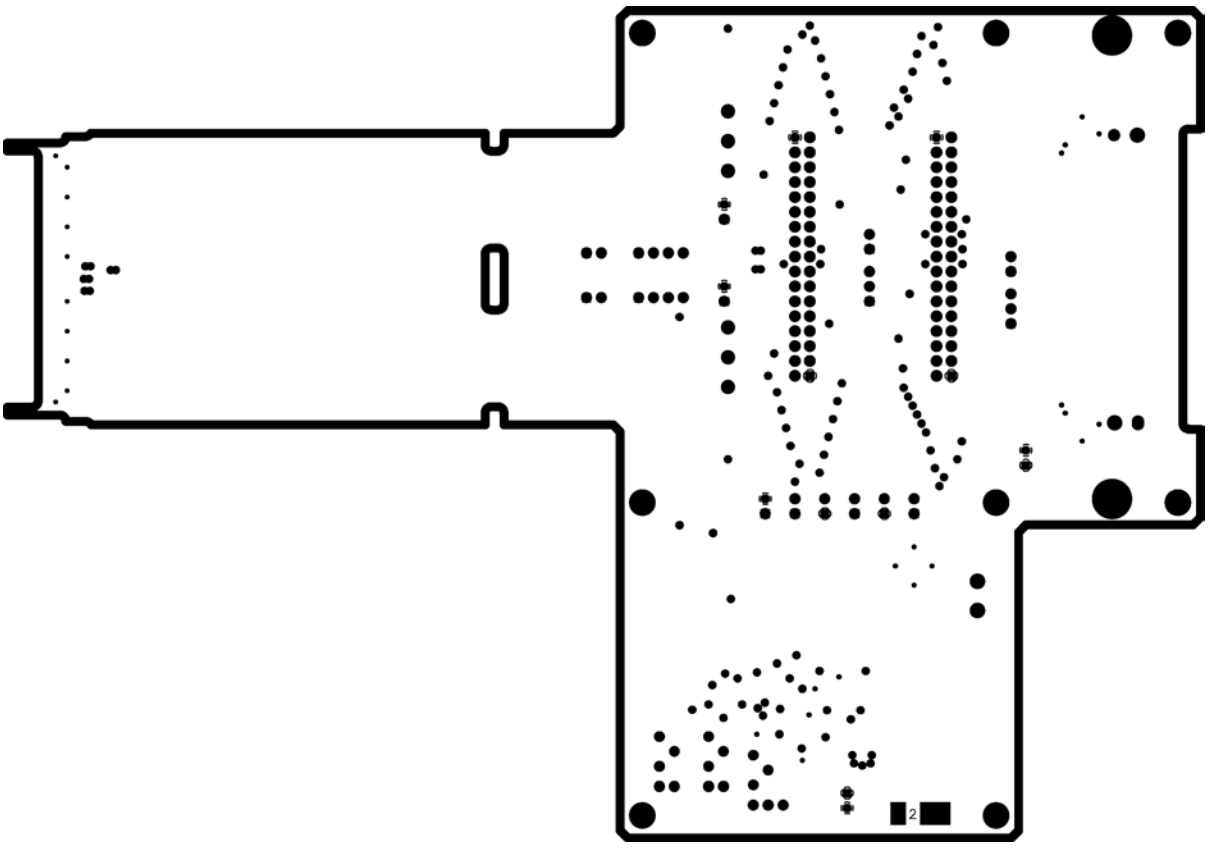

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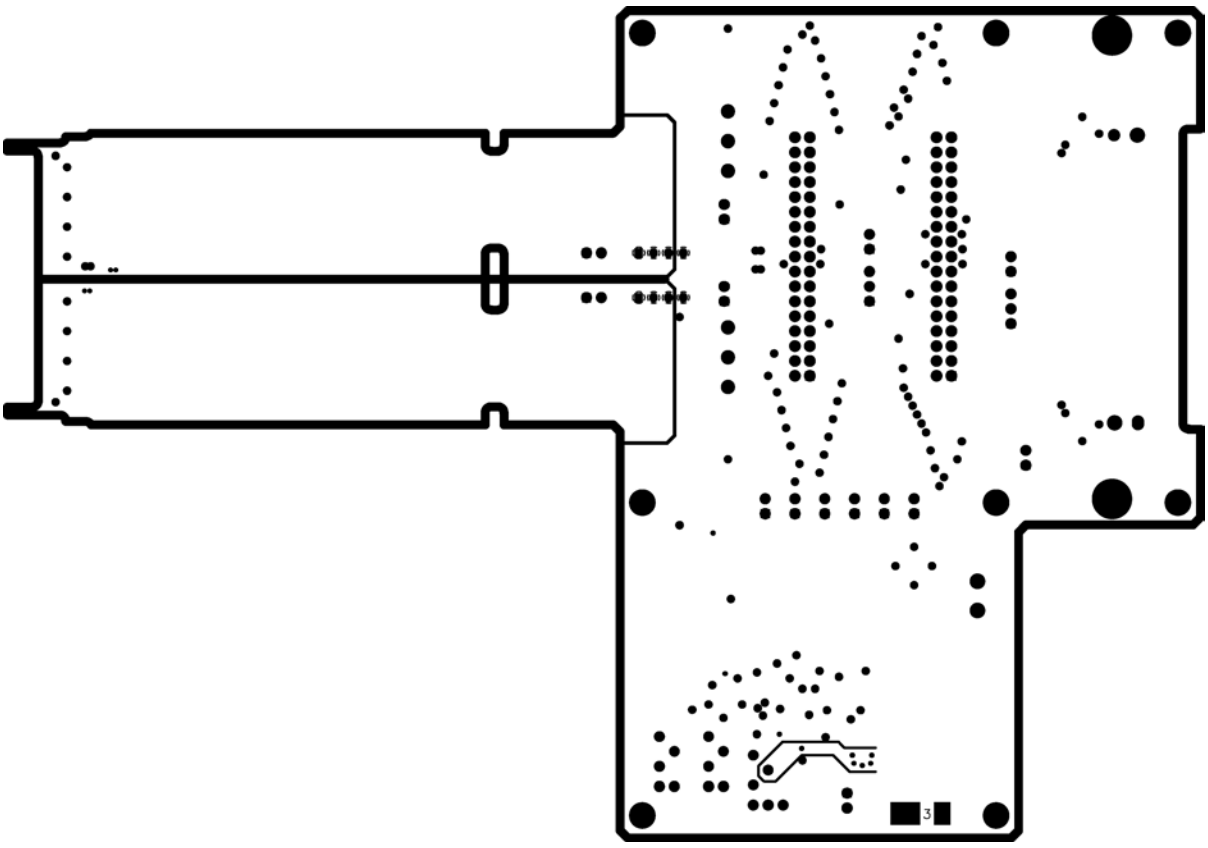

PCB Bottom Layer