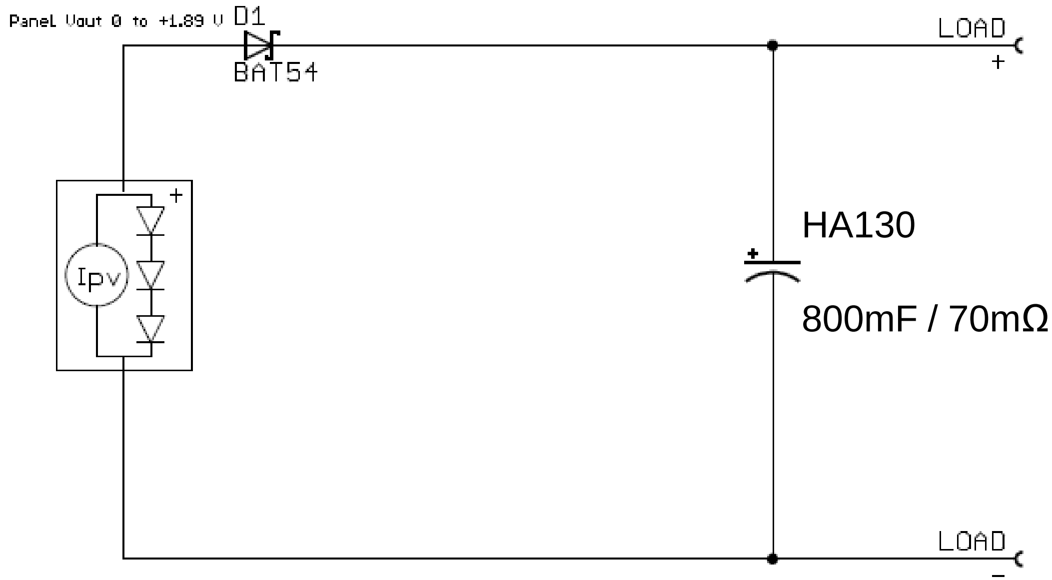
Charging a supercapacitor from a solar cell with a bq25504 PPT energy harvesting IC

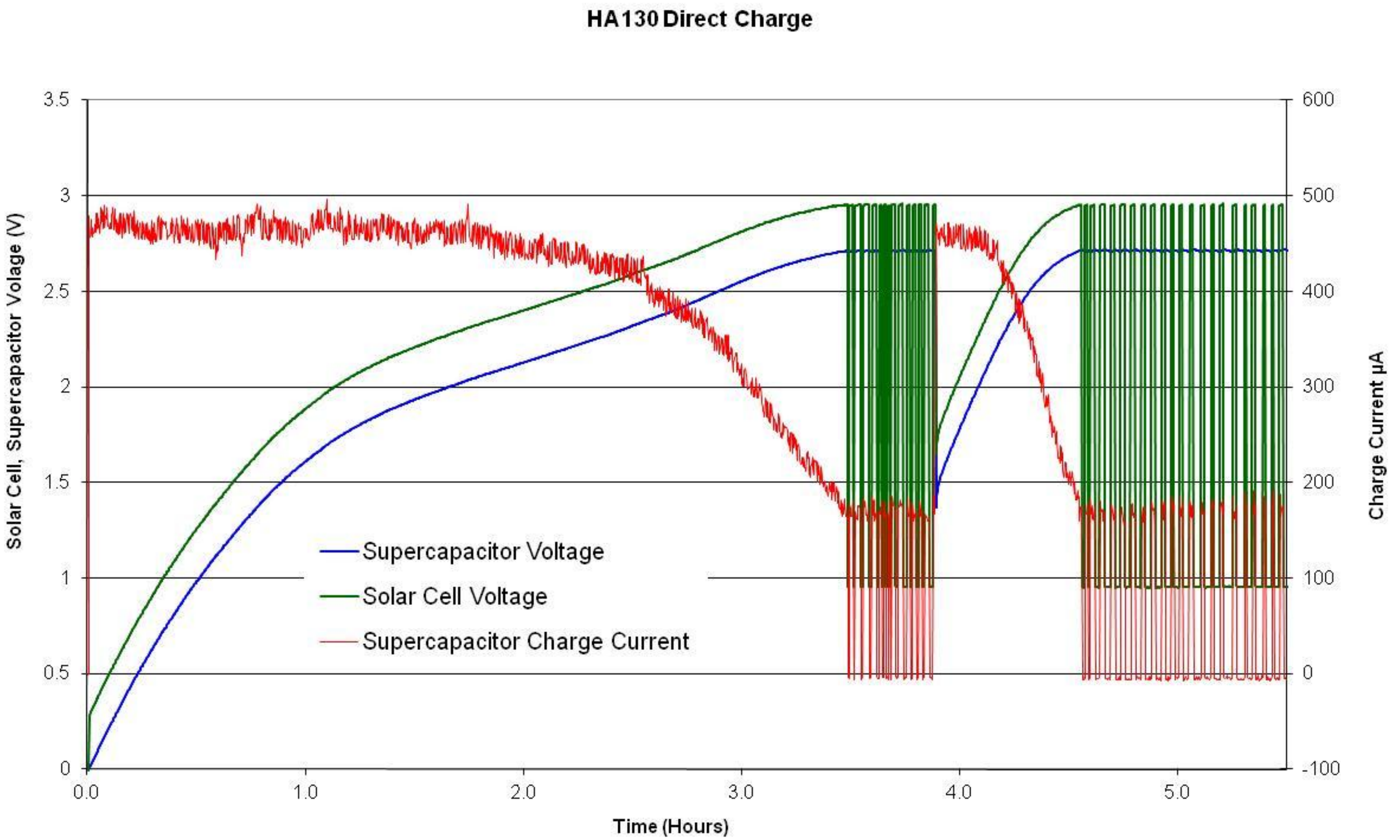
August, 2012

Direct Charging Circuit

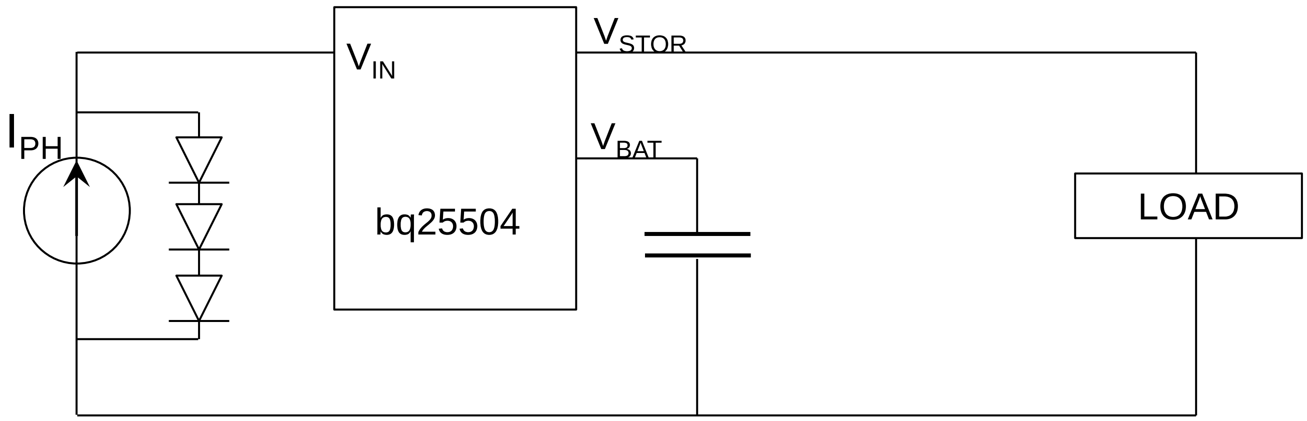


- Simplest circuit, starts charging from 0V
- V_{OC} < 2.7V at maxìmum light level
- D1 prevents the supercapacitor from discharging back into the solar cell when light levels fall
- BAT54 chosen for D1 due to low V_F. V_F is <0.1V at currents < 10μA
- HA130 provides excellent energy storage & power delivery
- **Fastest charge. But will NOT charge if V_{SOLAR} < V_{SCAP}** (e.g. if light level falls)

Fast Charging Waveforms

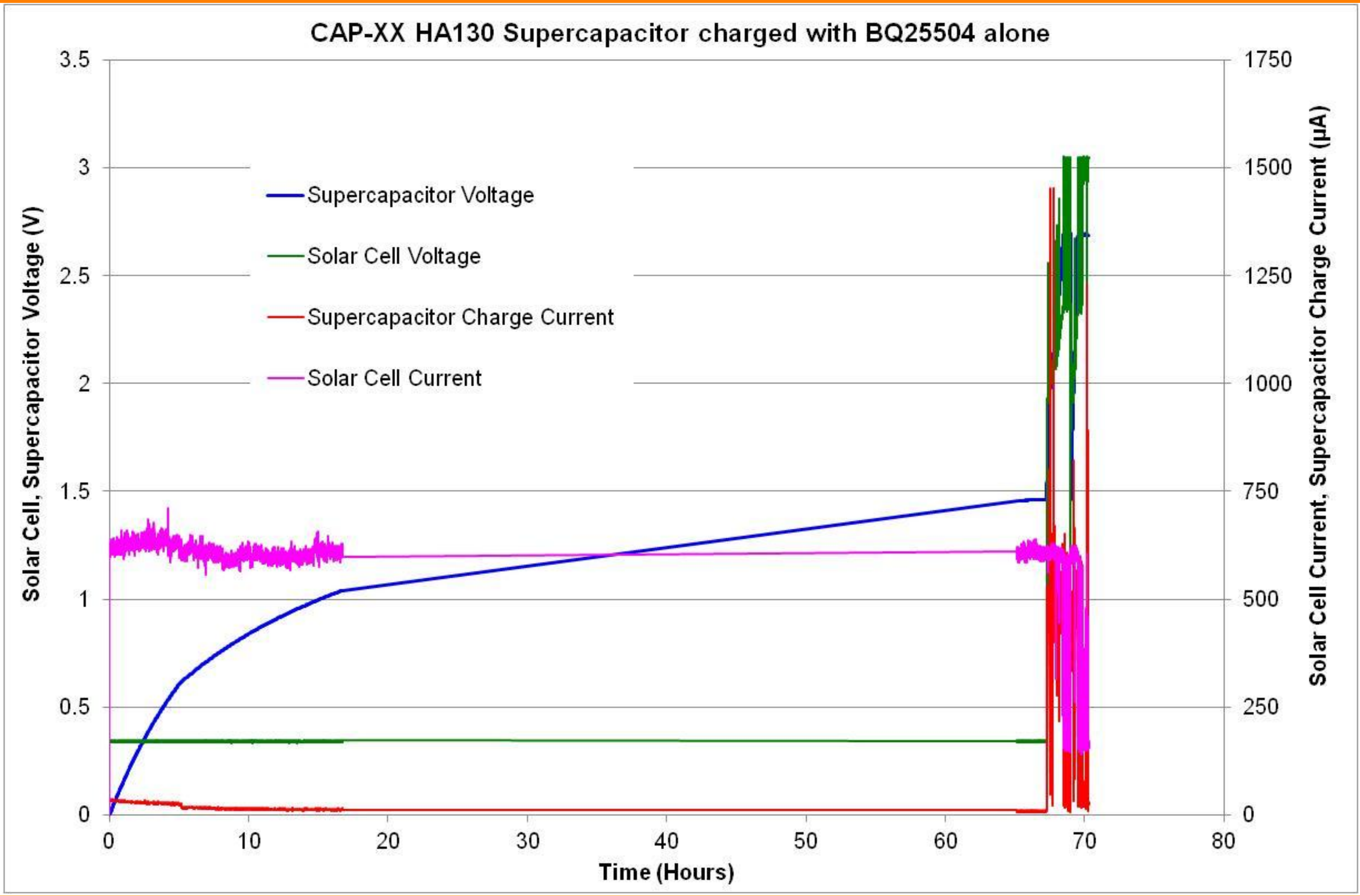


Charge with bq25504

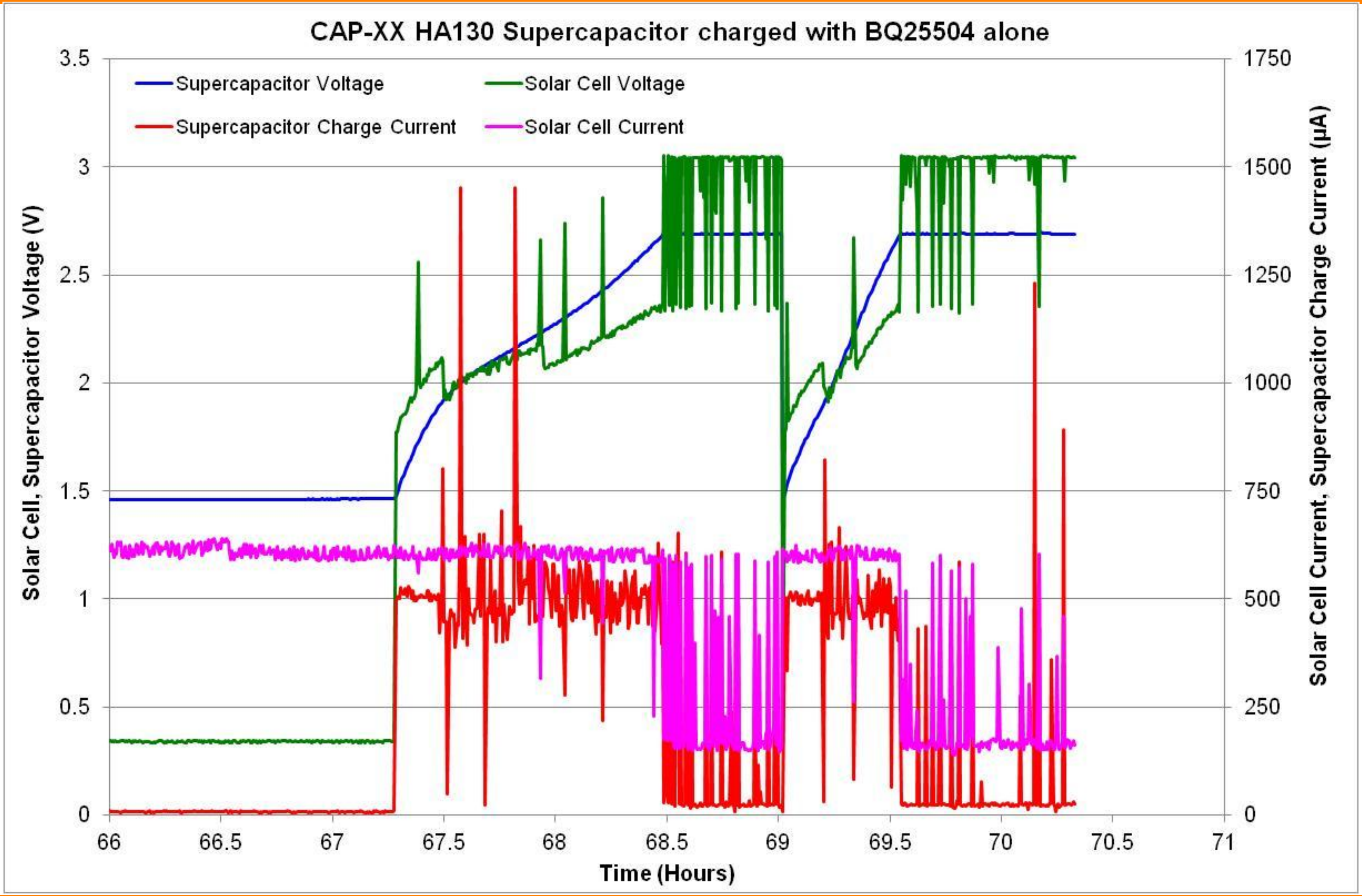


- Charge using bq25504 boost converter with Peak Power Tracking (PPT)
- The bq25504 has very inefficient “cold start” charging if V_{BAT} < ~1.5V
- It take ~67hrs for the bq25504 to charge an HA130 from 0V to 1.5V with a solar cell delivering 350µW peak power (“cold start”)
- It takes another hour to reach 2.7V with the boost converter running normally with PPT
- **Slowest charge. But WILL charge if $V_{SOLAR} < V_{SCAP}$ and $V_{SCAP} > 1.5V$**
(e.g. if light level falls with the supercapacitor partially or fully charged)

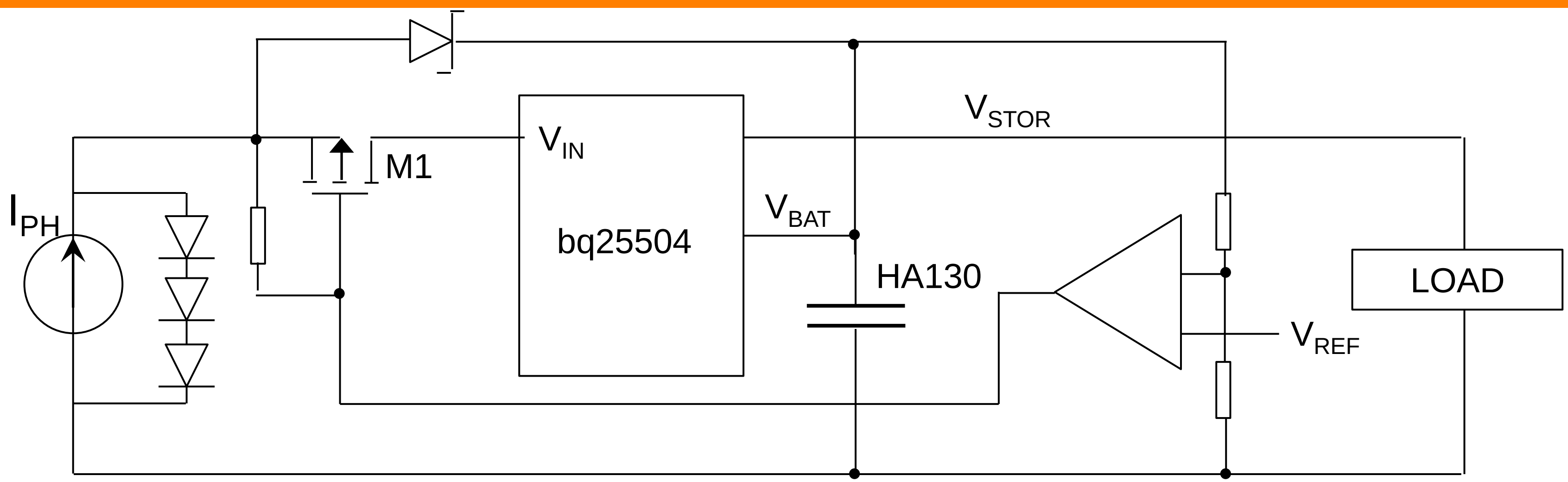
Charge with bq25504 Waveforms



Charge with bq25504 (last 5h)

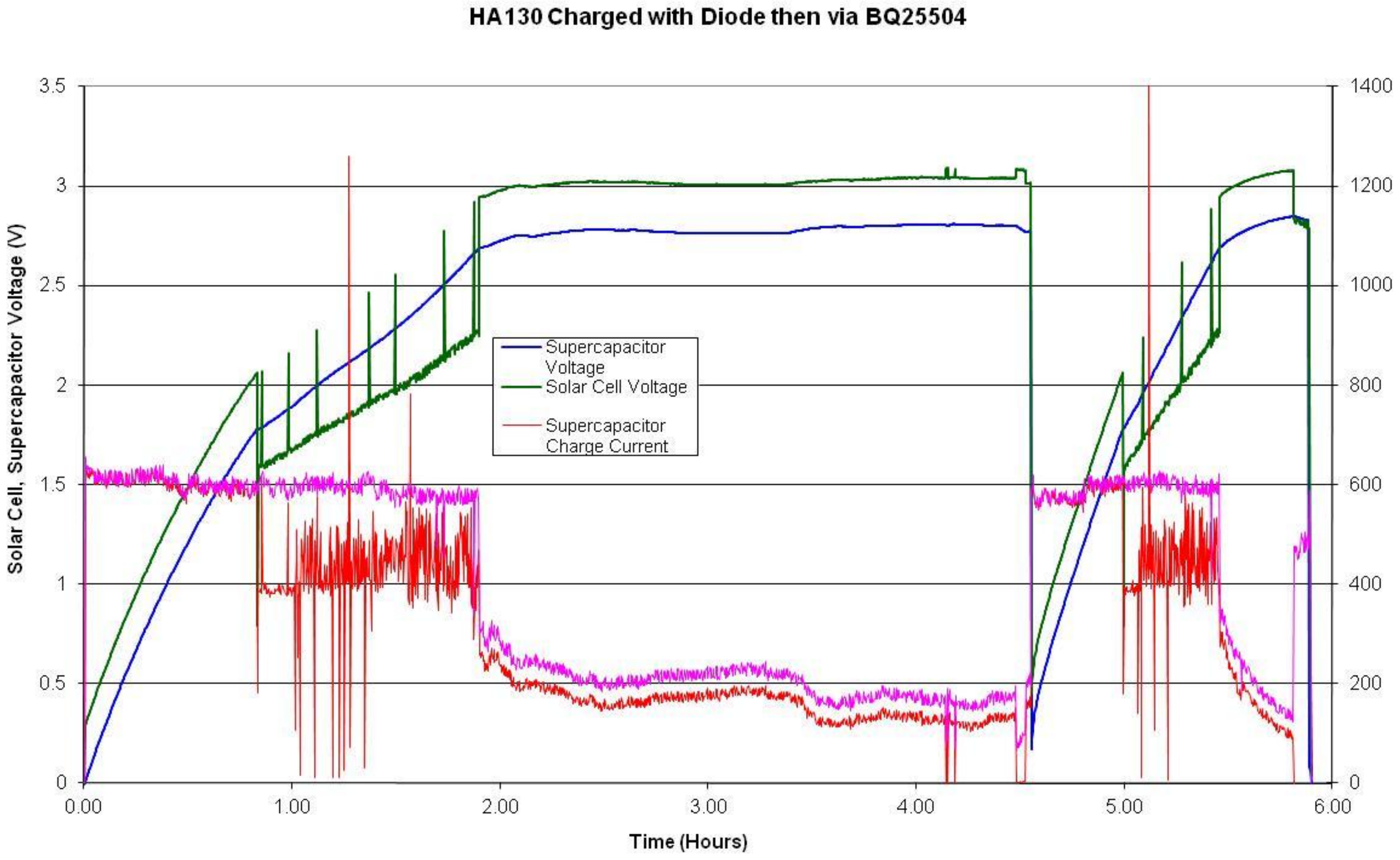


Charge with bq25504 with Diode Bypass for Rapid Charge from 0V

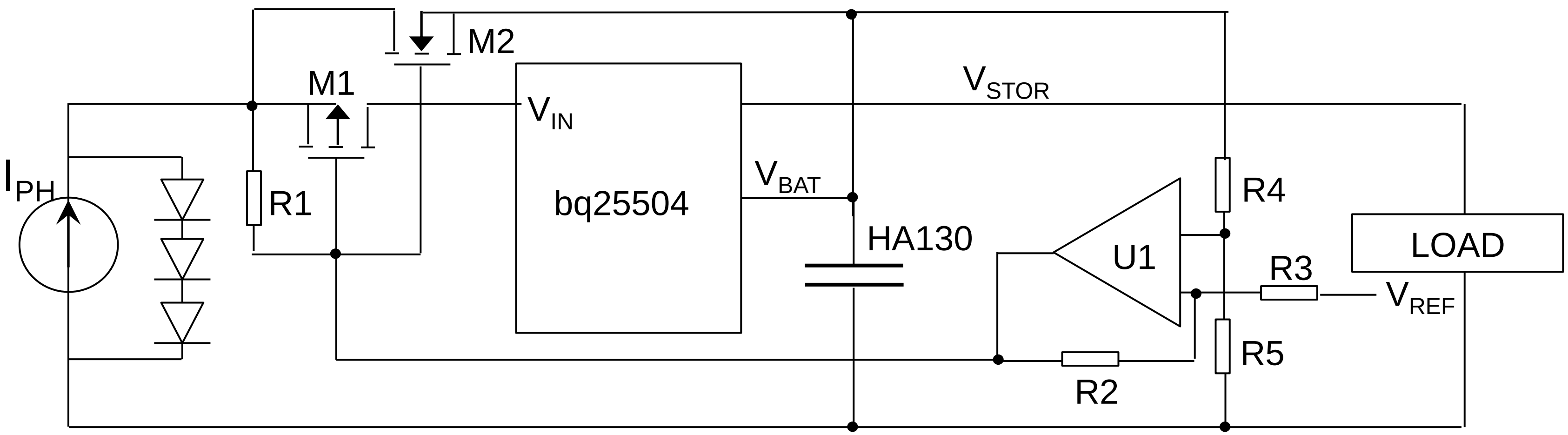


- Charge from 0V directly, using a diode to bypass the bq25504
- Much faster charging of supercapacitor to 1.5V. M1 is OFF, stopping the bq25504 from pulling down the solar cell voltage
- When the supercapacitor reaches ~1.8V, the comparator turns M1 ON, connecting the bq25504 to the solar cell
- Solar cell open circuit voltage < 3V to avoid over-voltage on the supercapacitor
- Achieves fast initial charge + fast charge with PPT once V_{SCAP} > 1.8V
- **Fast charge, and WILL charge if V_{SOLAR} < V_{SCAP} and V_{SCAP} > 1.5V**
  (e.g. if light level falls with the supercapacitor partially or fully charged)

Waveforms for Charging with bq25504 and Diode Bypass



Charge with bq25504 with NFET Bypass for Rapid Charge from 0V

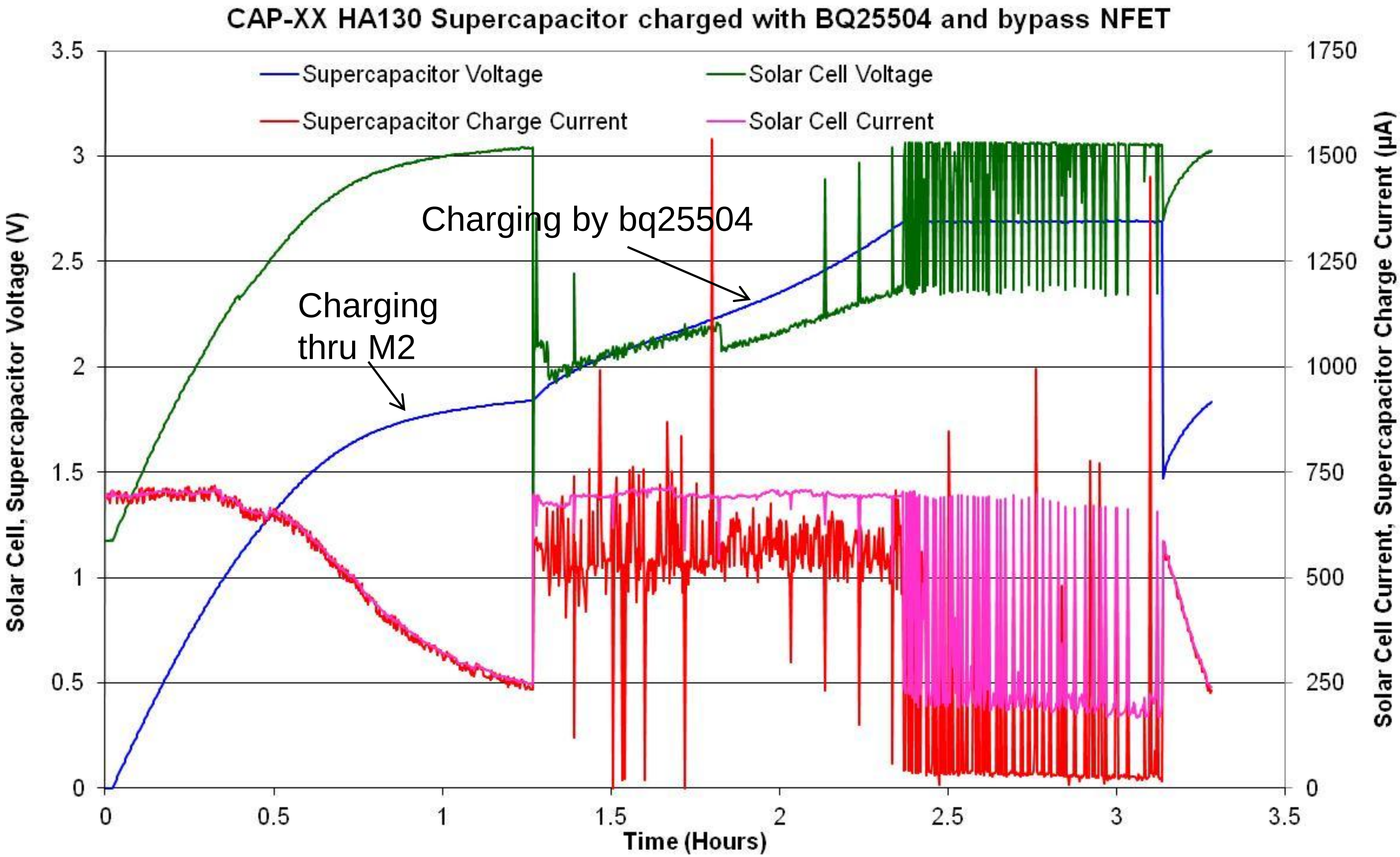


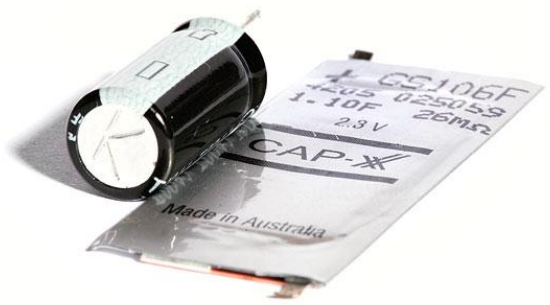
- Supercap charges directly from 0V using NFET M2 to bypass bq25504. M1 is OFF, stopping the bq25504 from pulling down the solar cell voltage
- When the supercap reaches ~1.8V, the comparator turns M1 ON, connecting the bq25504 to the solar cell, and turns M2 OFF, preventing the solar cell over-charging the supercap if $V_{SOLAR\_OC} > V_{SCAP\_MAX}$
- The supercapacitor target voltage is now set by the bq25504. **There is no possibility of the supercapacitor being over-voltage**
- Achieve fast initial charge + fast charge with PPT once $V_{SCAP} > 1.8V$
- **Fast charge, and WILL charge if $V_{SOLAR} < V_{SCAP}$ and $V_{SCAP} > 1.8V$** (e.g. if light level falls with the supercapacitor partially or fully charged)

Notes on the NFET Bypass Circuit

1. When the unit first powers ON with the supercapacitor at 0V, the source of M2 is at 0V, U1 is OFF and R1 turns M1 OFF, preventing the bq25504 from operating
2. When V_{SOLAR} > V_{GSTH} of M2, M2 starts to conduct, charging the supercapacitor
3. The resistance across M2 loads the solar cell so its voltage is just above M2(V_{GSTH}) + V_{SCAP} so the solar cell provides good charge current in reasonable light
4. When V_{SCAP} =1.85V, the o/p of U1 goes low, turning M2 OFF, and turning M1 ON. This enables the bq25504 when the voltage at V_{BAT} > V_{STOR_CHGEN}, so the IC always operates in PPT mode and never in cold start mode
5. Select a low power open drain comparator with in-built reference and which operates at a supply voltage down to 1.8V or less. In our example, we used a TLV3011, which has a typical quiescent current of 2.8µA and V_{REF} = 1.242V. An alternative is MAX9016 with a typical quiescent current of 1µA and V_{REF} = 1.236V
6. Select M2 with the lowest V_{GSTH} possible, with suitable size and gate charge. The lower the V_{GSTH}, the faster the supercapacitor will reach 1.85V and enable PPT mode in the bq25504. We have used an irlm6246, which has typical V_{GSTH} of 0.8V
7. The other components used in slide 9 were: M1 = FDV302P, R1 = 1MΩ, R2 = 10MΩ, R3 = 220KΩ, R4 = 680KΩ, R5 = 1.5MΩ.
8. The hysteresis in the circuit means U1 will go low when V_{BAT} > 1.85V and U1 will go open drain when V_{BAT} < 1.77V

Waveforms for Charging with bq25504 and NFET Bypass





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