Supercapacitors Enable μPower Energy Harvesters to Power Wireless Sensors and do other useful things

(Everything you wanted to know about supercapacitors and were afraid to ask)

Sensors Expo June 2019
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VP Quality & Applications Engineering

www.cap-xx.com
Energy Harvesting

- The environment has infinite energy, sensors are everywhere, so why have small energy harvesters not taken off as forecast?
Some Forecasts

  - Energy Harvesters markets at $131.4 million in 2012 are projected to increase to $4.2 billion in 2019. Growth is anticipated to be based on demand for micro power generation that can be used to charge thin film batteries. Systems provide clean energy that is good for the environment. Growth is based on global demand for sensors and wireless sensor networks that permit control of systems.

  - $500M in 2018 and forecast $1030M in 2025
  - List of key players shows this report also deals with micro power.
Hurdles for Small Energy Harvesters

- Price (CR2032 coin cell ~US$0.3)
- 10’s – 100’s µW
- Knowledge:
  - How do I get enough power with EH?
  - How do I keep size, cost down?
  - How do I avoid complexity?
  - Efficiency?

Solution:

Supercapacitors

Case Studies – visit us at booth 942
CAP-x

- Low cost
- Good energy density

But

- Need replacing, proper disposal (high cost)
- RoHS, SVHC, REACH (e.g. Mouser would not ship CR2032 to Australia, Element14 warning: Hazardous Item)
- High Internal impedance, especially when cold
- May have complex charging algorithm & capacity estimation
- Self discharge / leakage current

There may be additional transit time on this item. Delivery of other items on your order will be unaffected.
Supercapacitors

- “Infinite cycle life”, physical charge storage
- Excellent power density
- Wide temperature range, -40°C to +85°C
- Low leakage current [CAP-XX ~1µA/F]
- Great round trip efficiency (~99%)
- From small thin prismatic form-factors to large cans
- Simple to charge: Show me the current

An ideal power buffer

But
- Low voltage: may need cells in series → Need cell balancing
- Not SMD
Supercapacitor: an Ideal Power Buffer

- Supercapacitor charged at low average power
- Supplies peak power bursts (low ESR)
- Backup power in case of energy loss (high C)

Regulate duty cycle so Avge Pwr Out ≤ Avge Pwr In

80% efficiency

→ ~30µW  ➔ 150mW

Tx 1 message/hr, 150mW for 0.6s, avge pwr = 25µW
Supercapacitor Properties
What makes a Supercap “Super”?

A supercapacitor is an energy storage device which utilizes high surface area carbon to deliver much higher energy density than conventional capacitors.

**Basic Theory:**
Capacitance is proportional to the charge storage area, divided by the charge separation distance ($C \propto \frac{A}{d}$)

As area ($A$) $\uparrow$, and charge distance ($d$) $\downarrow$, capacitance ($C$) $\uparrow \uparrow \uparrow \uparrow \uparrow$

No dielectric, working voltage determined by electrolyte

**Basic Electrical Model:**
Electric Double Layer Capacitor (EDLC)

- **Nanoporous carbon:** Large surface area $> 2000 \text{m}^2/\text{gm}$
- **Electrolyte:** Ions in a solvent
- **Separation distance:** Solid-liquid interface (nm)
- **Separator:** Semi-permeable membrane
- **Electrode:** Aluminum foil
What makes CAP-XX “Super”?  

- Very small, very thin form factors  
- Ultra-low impedance (ESR)  
  - High power delivery (CAP-XX has world’s highest power density)  
- Very high capacitance (C)  
  - Provides the energy needed to keep delivering the power  
- Easy to charge  
  - Just need a charge current (from 20uA) & over-voltage protection  
- Very low leakage current (<1µA)  
- Unlimited cycle life (physical charge storage, no chemical reactions)  
- Excellent low temperature performance  
- Good frequency response
Volumetric Power Density vs Energy Density: Supercapacitors

- Cap-xx
- Maxwell Boostcap
- Illinois Capacitor - Prismatic
- Illinois Capacitor - Radial
- Maxfarad
- Murata
- Nesscap
- NEC/Tokin
- NEC/Tokin - Prismatic
- AVX
- Cooper Bussmann / Eaton
- Cellergy
- Panasonic
- Tecate - Prismatic
- Tecate - Radial
- Nichicon
- ELNA - Radial
- ELNA - Prismatic
- KEMET
- Rubycon
- Taiyo Yuden
Supercapacitors operate over a wide temp range

### Normalised ESR vs. temperature

- **H Series**
- **G Series**
- Poly. (H Series)
- Poly. (G series)

### Normalised DC capacitance vs. temperature

- **G Series**
- **H series**
...translates to Low Charge Current
Shallow discharge steady state $I_{\text{LEAKAGE}}$

HW109 Single Cells $I_{\text{Leakage}}$ following a shallow discharge

Blue Cells precharged for 100 hours at 2V7, Red Cells had no pre-charging time.

Discharged from 2V7 to 2V0 every hour then recharged through 2kΩ while monitoring $I_{\text{Leakage}}$.

Theoretical Charge Current

1.25µA

2.8µA

3.7µA

$1.25\mu A$ $2.8\mu A$ $3.7\mu A$
Poor Frequency Response ...
... But excellent pulse response

1.8A 1.1ms pulses supported by GW209, source current limited to 0.5A

- Voltage (V)
- Source Current (A)
- Load Current (A)
Effective capacitance is a time domain representation of freq response that can be used for a quick estimate of pulse response.
Effective Capacitance (GW209)

Percentage of DC capacitance (%) vs. Pulse Width (s)

- Percentage of DC capacitance (%) ranges from 0% to 100%.
- Pulse Width (s) ranges from 0.0001 to 10 seconds.

The graph shows the percentage of DC capacitance increasing as the pulse width increases.
Efficient Charge / Discharge Cycle

- Losses = $I^2R \times$ duration during charge, discharge
- Energy in/out = $2 \times \frac{1}{2} C \left(V_{\text{MAX}}^2 - V_{\text{MIN}}^2\right)$
- Efficiency = \[
\frac{\text{Energy in/out}}{\text{Energy in/out} + \text{Losses}} = \frac{\text{Energy in/out}}{\text{Energy in/out} + i^2.\text{ESR}.t}
\]

\[
= \frac{\frac{1}{2} C (V_2^2 - V_1^2)}{\frac{1}{2} C (V_2^2 - V_1^2) + i^2.\text{ESR}.C \frac{(V_2 - V_1)}{i}}
\]

\[
= \frac{V_2 + V_1}{V_2 + V_1 + 2. i. \text{ESR}}
\]

- Ex 1: GPRS 2A disch from 3.8V to 3.2V, ESR = 50mΩ, $\eta = 97.2\%$
- Ex 2: Charge @ 50mA from 3.2V to 3.8V, $\eta = 99.9\%$
Cell Voltage Balancing

- Supercapacitors are low voltage devices
- Modules containing 2 or more supercapacitors in series are needed to achieve higher operating voltages
- Multi-cell modules need voltage balancing to ensure that slight differences in leakage current do not cause voltage imbalances between the cells
- Without adequate voltage balancing, one cell may go over-voltage, leading to accelerated ageing & premature failure
- Balancing can be:
  - Passive (simple, but costly in terms of energy lost), or
  - Active (to achieve the minimum possible leakage current)
HA202 supercapacitors at 5V with no balancing

Terminal Voltage

Mid Point Voltage

Time (hrs)

0 10 20 30 40 50 60 70 80 90 100

0 1 2 3 4 5 6

1.5 1.7 1.9 2.1 2.3 2.5 2.7 2.9 3.1 3.3

Terminal Voltage (V)

Mid Point Voltage (V)

Time (hrs)

HA202 supercapacitors at 5V with no balancing

Terminal Voltage

Mid Point Voltage

0 10 20 30 40 50 60 70 80 90 100

0 1 2 3 4 5 6

1.5 1.7 1.9 2.1 2.3 2.5 2.7 2.9 3.1 3.3

Terminal Voltage (V)

Mid Point Voltage (V)

Time (hrs)
With balancing

GS206 @ 3.6V with balancing, midpoint voltages

- 68KΩ Resistive Balancing
- Active Balancing
Active Balancing with an Op Amp

- Low current rail-rail op amp, ~500nA
- Can source or sink current, 4.7mA
- Supplies or sinks the difference in leakage current between the 2 cells to maintain balance
- Total current, supercapacitor leakage + balancing circuit ~2µA
- Low cost op amp
Or Use a Single Cell

- If your circuit can run at 2.7V (prismatic) or 3V (cylindrical) or less, use a single cell
  - Simpler (no balancing required)
  - Cheaper
  - Thinner

- If source > 2.7V (or 3V) use a low power buck, e.g. TPS62743 (Iq 360nA), or LDO TPS78227 (Iq 500nA)

- Depends on energy / power required
- It’s a cost / size trade-off
- 3V prismatic cell coming !!
Sizing the Supercapacitor

- Energy balance approach often used:
  \[ \text{Avg Load Power} \times \text{Time} = E = \frac{1}{2} C(V_{\text{init}}^2 - V_{\text{final}}^2), \]
  \[ \therefore C = \frac{2E}{(V_{\text{init}}^2 - V_{\text{final}}^2)} \]

- But this implicitly assumes ESR = 0!

- This may lead to undersizing the supercapacitor.

- For constant current pulse of duration T:
  \[ V_{\text{drop}} = I_{\text{LOAD}} \times [\text{ESR} + \frac{T}{C_{\text{eff}}(T)}] \]

- For constant power it will be worse as \( I_{\text{LOAD}} \) increases as \( V_{\text{supercap}} \) decreases to keep \( V \times I = \text{const.} \). See CAP-XX website for tools that solve this problem
Equation for Constant Power

\[ V_{LOAD} = V_{SUPERCAP} - I_{LOAD} \cdot ESR \]

\[ P_{LOAD} = V_{LOAD} \cdot I_{LOAD} \]

\[ P_{LOAD} = (V_{SUPERCAP} - I_{LOAD} \cdot ESR) \cdot I_{LOAD} \]

\[ \therefore I_{LOAD}^2 \cdot ESR - V_{SUPERCAP} \cdot I_{LOAD} + P_{LOAD} = 0 \]

\[ I_{LOAD} = \frac{V_{SUPERCAP} \pm \sqrt{V_{SUPERCAP}^2 - 4 \cdot ESR \cdot P}}{2 \cdot ESR} \]

Iterate:

\[ V_{SUPERCAP}(t + dt) = V_{SUPERCAP}(t) - \frac{I_{LOAD}(t) \cdot dt}{C} \]

If load current is very small, \( I_{LOAD} \times ESR << V_{SUPERCAP} \) so use energy balance approach. Otherwise, use a spreadsheet to solve the above & simulate V & I over time, or use SPICE.
Constant Power Example

**HS130: 2.4F, 25mΩ supercapacitor module suppyling 1W for 4s**

- **Supercapacitor Voltage (V), Load Current(A)**
- **Time (secs)**

![Graph showing the performance of the supercapacitor module](https://www.cap-xx.com/resources/design-aids/)

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**Legend:**
- **Voltage**
- **Current**
- **Pwr Chk**
Supercapacitor Ageing

- Supercapacitors will slowly lose C and increase ESR over time.
- The rate of C loss, ESR rise is a function(V,T)
- CAP-XX has placed a range of parts at different voltage-temp combinations for ~1yr to determine ageing rates as functions of V, T.

For GS130N 1.8V:

- **C loss rate**: at 0.3376% per thousand hours from the previous value, at 23°C 1.8V
- **C loss rate**: at 0.7553% per thousand hours from the previous value, at 50°C 1.8V
- **C loss rate**: at 1.98% per thousand hours from the previous value, at 70°C 1.8V

ESR increases at:
- 0.4912mΩ every 1000 hours at 70°C 1.8V
- 0.265% increase from initial ESR per thousand hours, at 23°C 1.8V
- 1.83% increase from initial ESR per thousand hours, at 50°C 1.8V
Life Estimates

- Life is not a fixed end date. It is when the supercapacitor has lost C, increased ESR so it no longer supports your load.
- You can increase life by starting with a higher C, lower ESR supercapacitor.
- You should have a typical V-T operating profile:
  - Using the corner case (e.g. 5V, 70°C) is lazy and won’t work.
- Common Arrhenius assumptions:
  - Ageing rate halves for every 10°C decrease and every 0.2V decrease.
  - Only applicable if reactions stay the same – they don’t!
- CAP-XX has regressed eqns for Closs, ESRrise with V, T.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Voltage</th>
<th>% Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>-40°C</td>
<td>5</td>
<td>0%</td>
</tr>
<tr>
<td>-30°C</td>
<td>5</td>
<td>0%</td>
</tr>
<tr>
<td>-20°C</td>
<td>5</td>
<td>5%</td>
</tr>
<tr>
<td>-10°C</td>
<td>5</td>
<td>5%</td>
</tr>
<tr>
<td>0°C</td>
<td>5</td>
<td>10%</td>
</tr>
<tr>
<td>+10°C</td>
<td>4.8</td>
<td>20%</td>
</tr>
<tr>
<td>+20°C</td>
<td>4.8</td>
<td>20%</td>
</tr>
<tr>
<td>+30°C</td>
<td>4.8</td>
<td>10%</td>
</tr>
<tr>
<td>+40°C</td>
<td>4.6</td>
<td>10%</td>
</tr>
<tr>
<td>+50°C</td>
<td>4.6</td>
<td>10%</td>
</tr>
<tr>
<td>+60°C</td>
<td>4.5</td>
<td>5%</td>
</tr>
<tr>
<td>+70°C</td>
<td>4.2</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>
Claim: 0.77yrs @ 5V, 85°C

At 3.6V, using assumption of life doubling for every 0.2V reduction, life increased by $2^{(5V-3.6V)/0.2V} = 2^7 = 128$

Life at 3.6V, 85°C = 0.75 x 128 = 99yrs

Reducing temperature to 25°C increases life by a factor of $2^{(85-25)/10} = 2^6 = 64$

Life at 3.6V, 25°C = 99 x 64yrs = 6308yrs!
Use real estimates of Closs, ESRrise.

Determine min C / max ESR that will support your application:
- I.ESR Vdrop
- Constant power or constant current
- Ceff for short PW

Estimate a realistic V-T-T operating profile.

Apply C loss / ESR rise factor over required life to EOL C, ESR to determine initial C, ESR.
Supercapacitor Charging

A supercapacitor charging circuit must:

1. behave gracefully into a short circuit since a discharged supercapacitor will look like a short, or the in-rush current will have to be limited
2. be able to charge from 0V
3. provide over voltage protection for the supercapacitor
4. prevent the supercapacitor from discharging into the source when $V_{\text{SOURCE}} < V_{\text{SUPERCAP}}$

and

5. should be designed for maximum efficiency
SMALL SOLAR CELL REPORTING OVER A WIDE CAMPUS AREA
LoRa Case Study
Power output for solar cells is typically defined at 50,000 lux (bright sunlight) or 100,000 lux (1kW/m²).

If used indoors, light levels are MUCH lower: Typically between 300 lux (minimum for easy reading) & 500 lux (well it office) AND with different spectrum (LED/CCFL).

Select & characterise your solar cell for the conditions in which it will be used!

Indoor use: LED/CCFL spectrum, typically 200 – 400 lux. Silicon cells will not do well!
Epishine: Organic solar cell, lower cost and more responsive to indoor LED / CCFL. 250µW @ 500 lux LED spectrum, 29mm x60mm, 14.4µW/cm². Voc, Vpp approx. constant

Vpeak_PWR = 2.7V @ 500 lux

Vpeak_PWR = 2.4V @ 50 lux
What is the best charging circuit?

It depends:

- Direct charging or use a Power Management IC?
- Direct Charging
  - Simple, low cost
  - Sufficient light when application needs to run, e.g. working hrs in a supermarket, office, factory; in daylight
- Energy Harvesting PMIC
  - Boost with Max Peak Power Tracking
  - Will still charge when light low, $V_{solar} < V_{min}$ for application to work
  - May include cell balancing
  - May include duty cycle regulation
Simplest Solar Charging Circuit

- Single cell supercapacitor. No balancing. Starts charging from 0V
- \( V_{\text{solar}} - V_{\text{diode}} \geq V_{\text{load\_min}} \) when the application needs to run
- \( V_{\text{solar\_oc}} \leq V_{\text{scap\_rated}} \) at the maximum light level in the application (2.7V in this case) \([V_{\text{diode}} \to 0 \text{ as supercap fully charged}]\)
- D1 prevents the supercapacitor from discharging back into the solar cell when light levels fall
- BAT46 chosen for D1 due to low \( V_F \). \( V_F \) at currents < 10\( \mu \)A, <0.1V
Direct Charging Solar Charging Circuit

- Single cell supercapacitor. No balancing. Starts charging from 0V
- \( V_{\text{solar}} - V_{\text{diode}} \geq V_{\text{load}\_\text{min}} \) when the application needs to run
- Shunt regulator limits \( V_{\text{load}} \leq V_{\text{scap}\_\text{rated}} \).
  - Low current
  - No losses when \( V_{\text{solar}} < V_{\text{scap}\_\text{rated}} \)
- \( D1 \) prevents the supercapacitor from discharging back into the solar cell when light levels fall
- \( \text{BAT46} \) chosen for \( D1 \) due to low \( V_F \). \( V_F \) at currents < 10\( \mu \)A, <0.1V
Direct Charge or use EH PMIC?

If Voc > Vtarget at all light levels when app must run then direct charging is a good option.

Epishine Voc not dropping significantly at lower light levels is suitable for direct charging.

PMIC has ~80% - 90% efficiency
LoRa Setup

- Supply voltage range, 3.3V – 1.8V
- Use Epishine solar cell to directly charge a HA102 supercapacitor to 2.7V, using CAP-XX eval board APPEB1011, see www.cap-xx.com
- Supercapacitor can support multiple transmissions
- Regulate duty cycle so Vscap does not discharge below 2.4V
Sizing the Supercapacitor: discharge while transmitting

- Avg current = 10mA for 5.2s
- Peak Current = 62mA. PW 60ms
- Set voltage range 2.7V - 2.4V
- 1st approx (ignore ESR)
  - C ≥ 10mA x 5.16s / 0.3V
  - ≥ 172mF
- Select HA102, 240mF, 60mΩ ESR
- dV = 10mA x 5.16s / 0.24F + 0.062 * 0.06 = 0.22V

Graph showing the voltage and current over time.
Supercapacitor Direct Charging Circuit

- AN1007 Charging a Supercapacitor from a Solar Cell Energy Harvester
- APPEB1011 Direct Solar Cell Charging
- APPEB1012 Solar cell charging with PMIC

LoRa demo Duty Cycle Regulation at 500lux

- Supercapacitor charged, load connected
- Load disconnected, solar cell charging supercapacitor
- Transmission burst, supercapacitor discharging
- Supercapacitor discharged to lower voltage threshold, disconnect load.

Solar cell selected with direct charging of a CAP-XXX HA102
240mF single cell supercapacitor supports 4 transmission bursts lasting 5.2s every 2 mins

- Duty cycle managed by µController, turn load on when supercap reaches upper threshold, turn load off when supercap reaches lower threshold.
- Lower threshold set above brown out voltage – clean reset.
- Interval between transmit bursts depends on light level, brighter light → shorter interval
- See the demo, visit us at booth 942
SMALL SOLAR CELL
SUPPORTING CELLULAR IoT
NB IoT/LTE CAT M1 Case Study
NB IoT / LTE CAT M1 Setup

- Report messages from the Arduino µC managing a Ublox IoT module
- Supply voltage range, 4.5V – 3.3V
- Use GaAs solar cell to charge 2.5F supercapacitor to 4.5V with a PMIC using CAP-XX eval board APPEB1012, see www.cap-xx.com

**CAP-XX**

2 x 5F, 2.5V supercapacitor cells in series

Ublox IoT module

Solar cell

Charging circuit with PMIC

CAP-XX controller PCB
Characterise your solar cell

Lightricity: GaAs solar cell, most efficient in indoor LED / CCFL light. 687µW @ 500 lux LED spectrum, 48mm x41mm, 34.9µW/cm².

4s2p configuration, Voc < Vtarget, use a boost to charge the supercap
Selecting Your Charging IC

<table>
<thead>
<tr>
<th>Attribute</th>
<th>AEM10941</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min cold start voltage</td>
<td>380mV</td>
<td>The lower the better.</td>
</tr>
<tr>
<td>Cold start charge</td>
<td>Rapid. Boost charges 22μF (typ) cap.</td>
<td>How the IC boosts the input voltage during cold start to reach the internal voltage required to run as a boost.</td>
</tr>
<tr>
<td>Cold start power</td>
<td>3μW</td>
<td>The lower the better, but must be &lt; power available from the solar cell at min light levels at which the unit must charge.</td>
</tr>
<tr>
<td>Cold start threshold</td>
<td>380mV</td>
<td>Voltage at which the IC starts operating as a boost converter, the lower the better</td>
</tr>
<tr>
<td>Vin min after start up</td>
<td>50mV</td>
<td>Min i/p voltage for the boost to keep operating once it has started</td>
</tr>
<tr>
<td>Quiescent current</td>
<td>&lt; 1μA</td>
<td>Current drawn by the IC while operating as a boost. Vbatt ≥ 2.5VThis is reflected in the low power efficiency.</td>
</tr>
<tr>
<td>Max Peak Power Tracking</td>
<td>Samples Vsolar_oc every 5s to set MPPT</td>
<td>Periodically disconnecting the i/p to sample Voc is the preferred method. MPPT then set as % of Voc. Can set MPPT at 70%, 75%, 85%, 90% of Voc. Some ICs set this as a fixed value which only works in constant light.</td>
</tr>
<tr>
<td>SCAP Bal.</td>
<td>Yes</td>
<td>Includes balancing cct for dual cell supercaps</td>
</tr>
<tr>
<td>Duty Cycle Ctrl</td>
<td>Yes</td>
<td>Status bit that reflects if supercap within desired voltage range</td>
</tr>
<tr>
<td>Efficiency</td>
<td>~90% at Peak Pwr Pt</td>
<td>90% is excellent efficiency at such low power. Vscap &gt; Vsolar</td>
</tr>
<tr>
<td>Hysteric operation</td>
<td>Yes</td>
<td>The boost converter turns off when Vcap reaches its desired voltage and turns on again when Vcap has discharged to a lower threshold. Saves power.</td>
</tr>
<tr>
<td>Max current</td>
<td>100mA</td>
<td>From energy harvester to boost converter</td>
</tr>
</tbody>
</table>
Supercapacitor charging cct with PMIC

Refer to:  
AN1007 Charging a Supercapacitor from a Solar Cell Energy Harvester  
AN1012 Supercapacitor powered NB IoT LTE CAT-M1  
User Manual for APPEB1012 Solar cell charging with PMIC
**APPEB1012 AEM10941 Duty Cycle Regulation**

**STATUS[0]** controls connection of load to supercap

- **Vscap < Vovdis**, **STATUS[1]** turns on to warn of LDO shutdown in 600ms
- **STATUS[0]** and **STATUS[1]** go LOW and LDO shuts down

- **Vscap > Vsolar**, **PMIC** starts operating as a boost

**Vscap > Vsolar**, **PMIC** starts operating as a boost
Load Power & Energy, Sizing the Scap

LTE CAT-M1 Demo running with a 2.5F dual cell

Vchrdy = 3.67V, Vovdis = 2.8V
Hard cutoff at 2.8V prevents brown out

Vdrop = 63mA x 36.6s / C < 4.5V - 3.3V = 1.2V
C > 0.063 x 36.6 / 1.2 = 1.92F

Select 2 x GY12R710020S505R, 5F, 170mΩ cells in series: C = 2.5F, ESR = 340mΩ
Vdrop = 0.063A x 36.6s / 2.5F + 0.18A x 0.34Ω = 0.98V

Final peak = 180mA
Regulating the load, Tx interval

- At 500 lux, solar cell delivers 687µW
- Supercapacitor discharge (excl ESR drop) = 0.92V
- Energy loss = \( \frac{1}{2} \times 2.5F \times (4.5^2 - 3.6^2) = 9.1J \)
- Time to re-charge supercapacitor = \( \frac{9.1J}{687\mu W} = 13246s = 3.7hrs \)
- Fine if this is suitable for whatever you are monitoring, e.g. a slowly moving variable
- Otherwise increase power by: larger solar cell, more light, other energy source, etc.
- Large energy requirement for Tx since unit disconnected between transmissions to reduce power, so need to log on to network every time. If you can increase EH power to support unit being always connected to the network, then energy for each transmission greatly reduced.
SUPPORTING a WiFi GATEWAY by WIRELESS CHARGING A SUPERCAPACITOR
WiFi Gateway Setup

- Report light level from the Adafruit to a web page
- Supply voltage range, 5V – 3.3V
- Use NFC Wireless Charger, see App Notes AN1009 Wireless Charging and AN1014 Supercapacitor Powered Wifi IoT, www.cap-xx.com
Characterising the Charger

NFC coil V-I plot with custom NFC charger

Max pwr 94mW
Diode Bridge prevents supercapacitor discharging back into the coil

Shunt regulator protects supercapacitor from over voltage.
WiFi IoT with 2.5F 5.5V module transmission waveform

Transmission time varies from 5s to 40s depending on signal strength and time taken to log on to WiFi network.

Average current during transmission = 73mA
Vdrop < 5V = 3.3V = 1.7V
Peak at the end = 88mA
C > 40s x 0.073A / 1.7V = 1.7F.

Select CAP-XX 5.5V 2.5F, 340mΩ module, GY25R51022S255R0.

Vdrop = 0.073A x 40s / 2.5F + 0.088A x 0.34Ω = 1.2V
Charging the supercapacitor

NFC charging 2.5F Supercapacitor for WiFi IoT

- Voltage (V) vs. Time (s)
- Current (A) vs. Voltage (V)
- Supercapacitor Voltage
- Charging Current
COMING SOON
THIN 3V PRISMATIC CELLS SAMPLES Q4 2019

We have 3V cylindrical cells now. Thin prismatic cells are more challenging. Ideal across CR2032 3V coin cells (no cct reqd) or with a small EH to store more energy or to enable direct charging.
3V cells, excellent life: 3V, 70°C

Test Cells C & ESR over time at 3V, 70°C

~13% Closs, IEC62391
Endurance spec is 30%

1.12 x ESRinit, IEC62391
Endurance spec is 4 x ESRinit
CAP-X

- Target specs:
  - 3V, -20°C to +70°C
  - 500mF
  - ESR < 200mΩ
  - IL < 2µA
- HA130 size (20mm x 18mm x 1.7mm)
  - Fits over CR2032 coin cell
- Place directly across a 3V coin cell
  - No extra circuit required
- Higher energy for EH apps
  - 3V → 2V 50% more energy than 2.7V → 2V
- Supercapacitors enable µPower energy harvesters to power wireless sensors with high power bursts

- Supercapacitors are ideal power buffers
  - High C (enough energy to do the job)
  - Low ESR (high power delivery)
  - Wide temperature range of operation
  - Easy to charge (show me the current)
  - Low leakage current & Excellent round trip efficiency

- Supercapacitor Charging
  - Into a S/C, from 0V, O/V protection, cannot discharge into the source

- Characterise your Energy Harvester

- Sizing the supercapacitor
  - Allow for I.ESR voltage drop
  - Constant current or constant power?
  - Ceff for narrow pulse
  - Easy to charge (show me the current)
  - Low leakage current & Excellent round trip efficiency
  - Ageing (need real data, Arrhenius a gross approximation)

- Case studies
  - LoRa
  - Cellular IoT (LTE CAT M1)
  - WiFi IoT

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