Nuances in Ultra-Low Power Designs for Wearable Products

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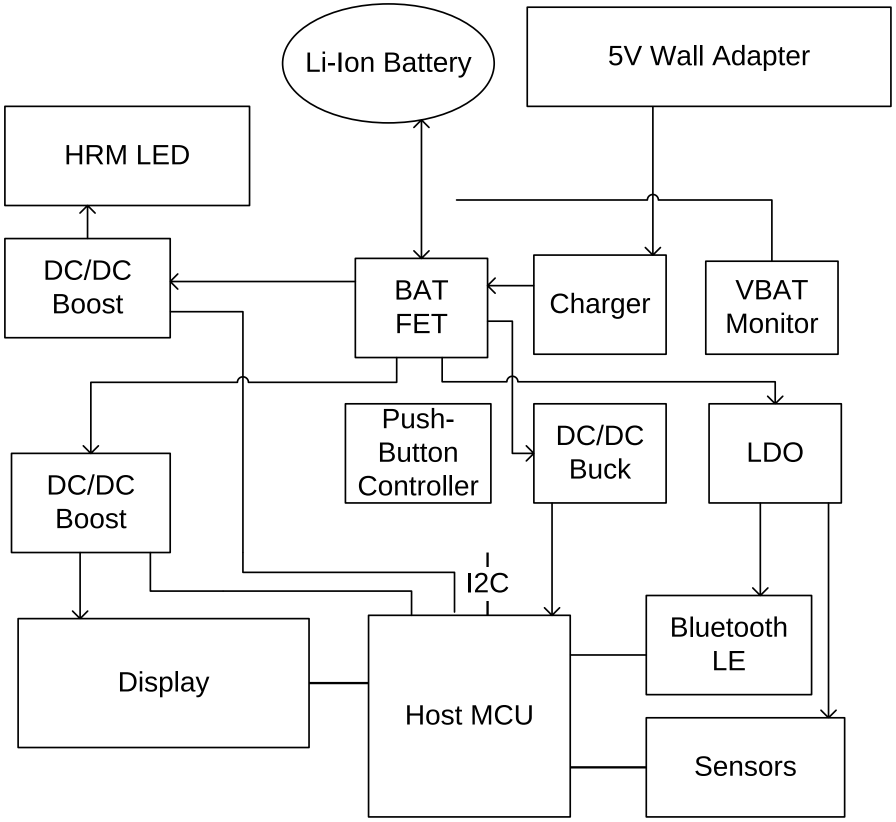
March 2016

Why is Low Power Needed?

- Wearables consist of many functions
  - Small Battery with Charger
  - Display (AMOLED, PMOLED, LCD, eInk, etc.)
  - Radio (BLE, WLAN, LTEM, etc.)
  - MCU (microcontroller to mobile chipset)
  - Sensors (6-axis sensor, temperature, humidity, light, heart rate, etc)
  - Vibration Motor
- How long the battery lasts depends on carefully managing each function



Why is Low Power Needed?

- Wearable Device Power
  - Requires Small Size to be Worn on the Body

  BUT
  - More Functionality = Greater Power Usage
  - Greater Power Usage = Larger Battery Capacity
  - Larger Battery Capacity = Larger Physical Size

- A better approach:
  - Create separate power domains for each key function
  - Determine the best power approach and maximize the solution based on
    - Function
    - Size
    - Cost

Optimizing Power Domains

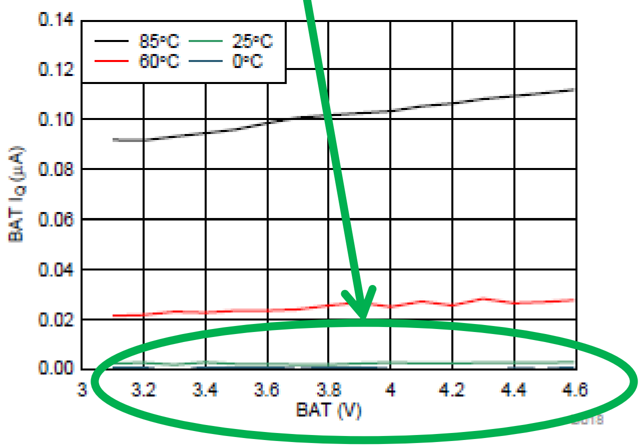
- Complex Wearable Systems = Multiple Power Domains

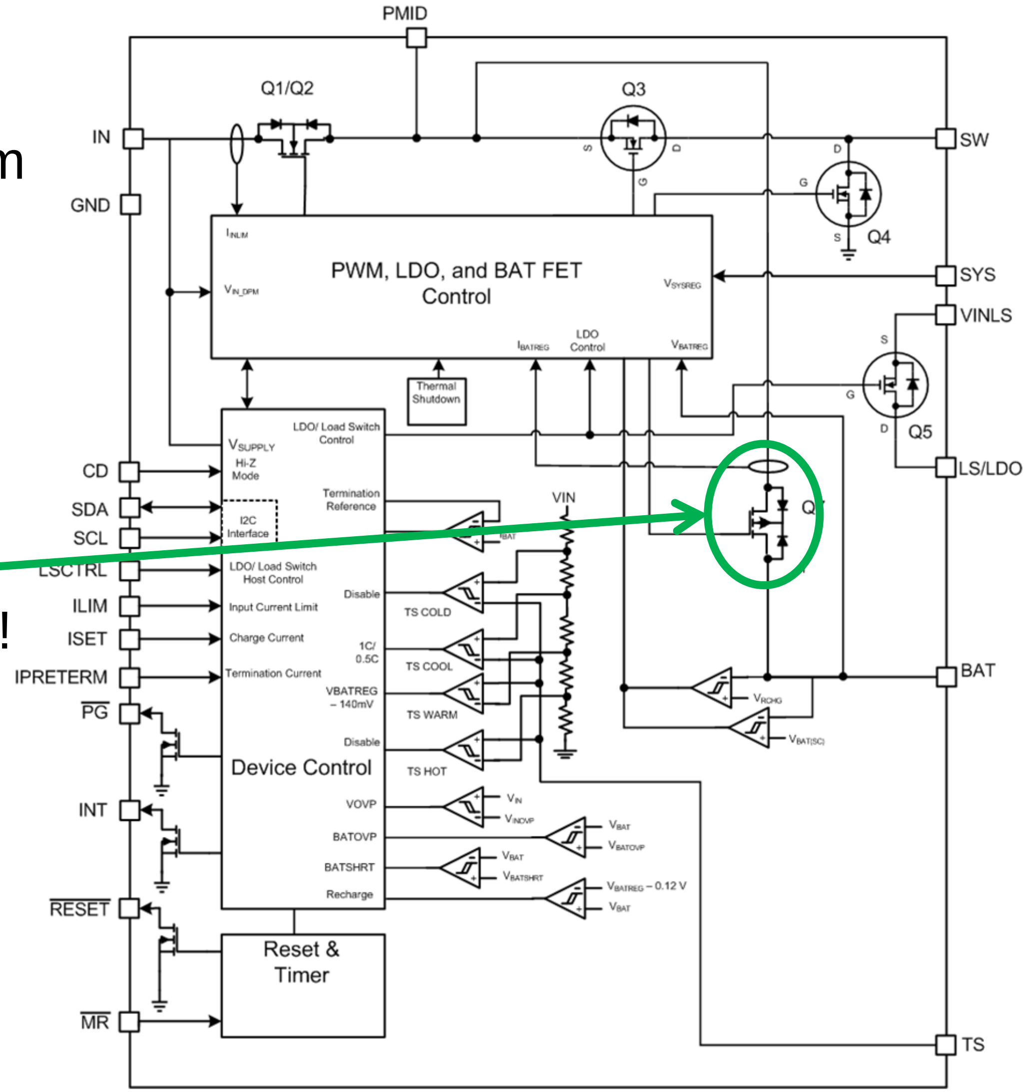
- Some domains focus on lowest leakage when off
  - Good candidates are radio's and highly duty cycled functions that are not time dependant
- Some domains focus on lowest power when in standby
  - Good candidates are processors and sensors that are low power in standby, but need to be able to respond quickly
- Some domains focus on highest efficiency when in use
  - Good candidates are the highest power consumption devices

- Additionally, for the best "Out of the box experience" you need to ensure that the battery does not die while the product is on the shelf ready for sale!

Low Off Current – Ship Mode

- Choose an architecture that can disconnect the battery from the rest of the system for the lowest leakage when the device is being shipped or on the shelf
- Power Path chargers have a BAT FET that enables this function to ~2nA at room temp!



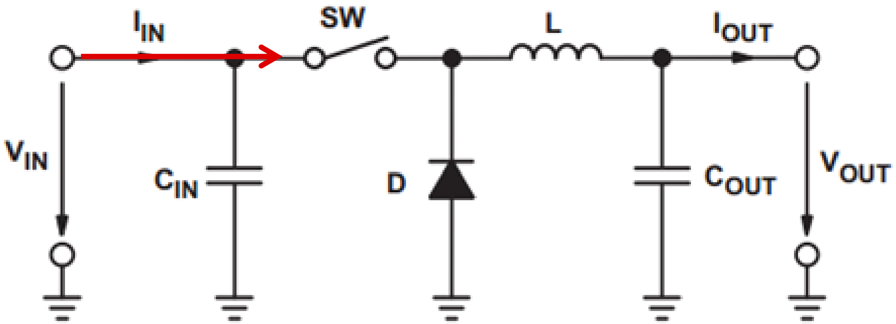


Example: bq25120

Low Off Current – True Disconnect Switch

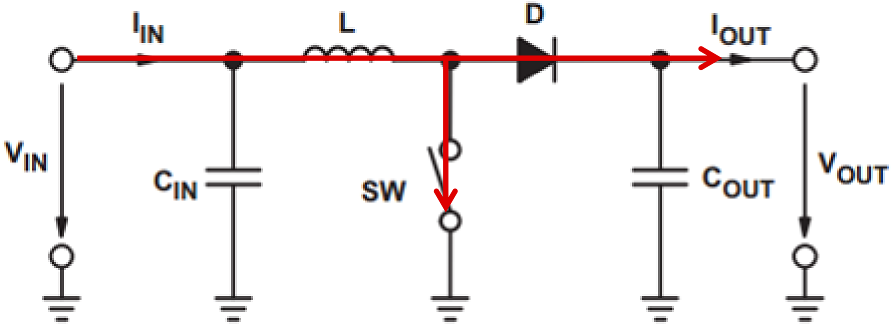
- When a sub-system is 'off' → you want 0 current consumption
  - This is not physically possible – some nA always remain
- All systems have leakage currents
  - This is the current consumed when it is 'off'
- Different DC/DC topologies have different leakage paths

Buck



Leakage is mainly in high-side FET

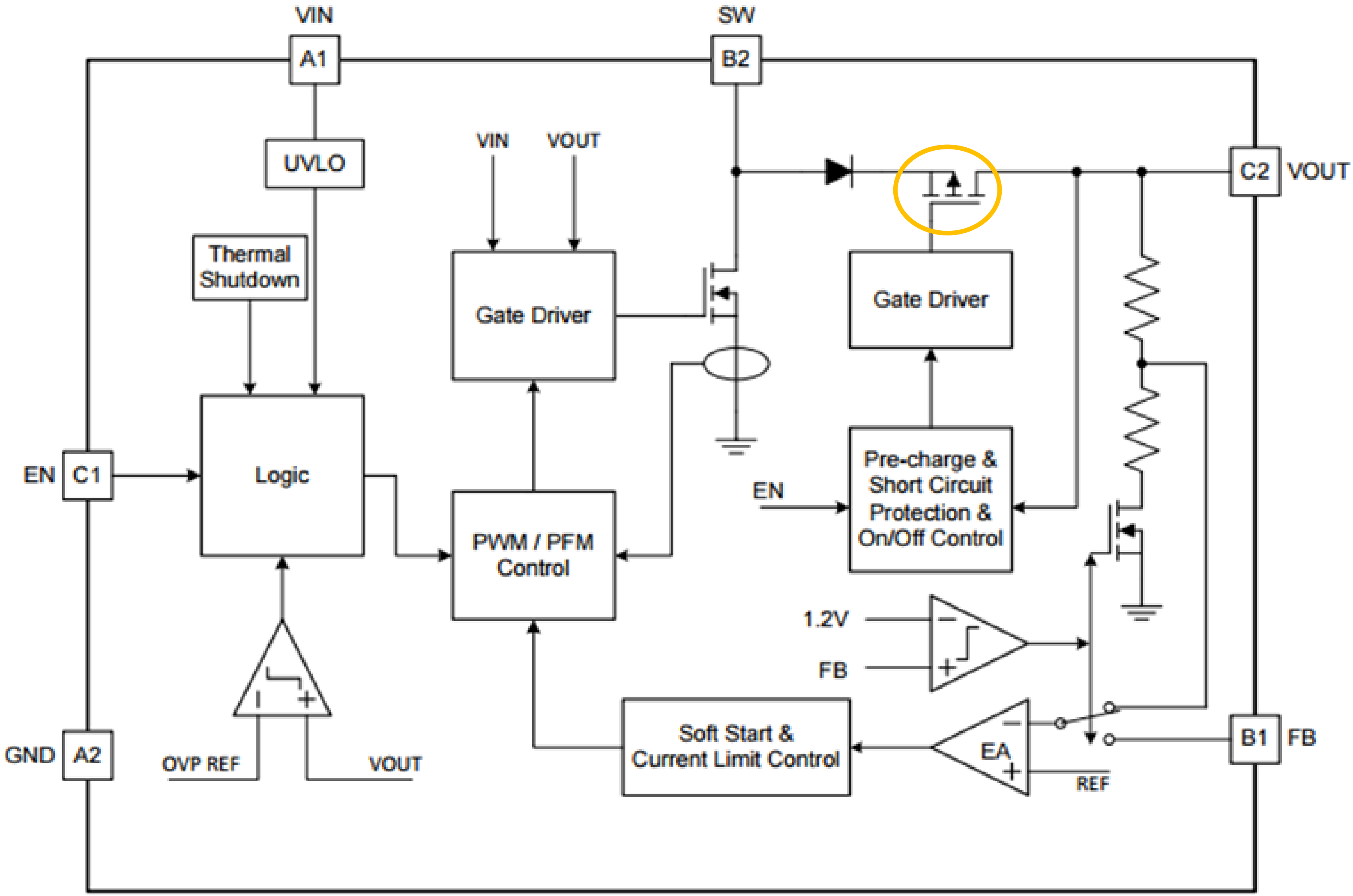
Boost



Leakage is in low-side FET
and to output!

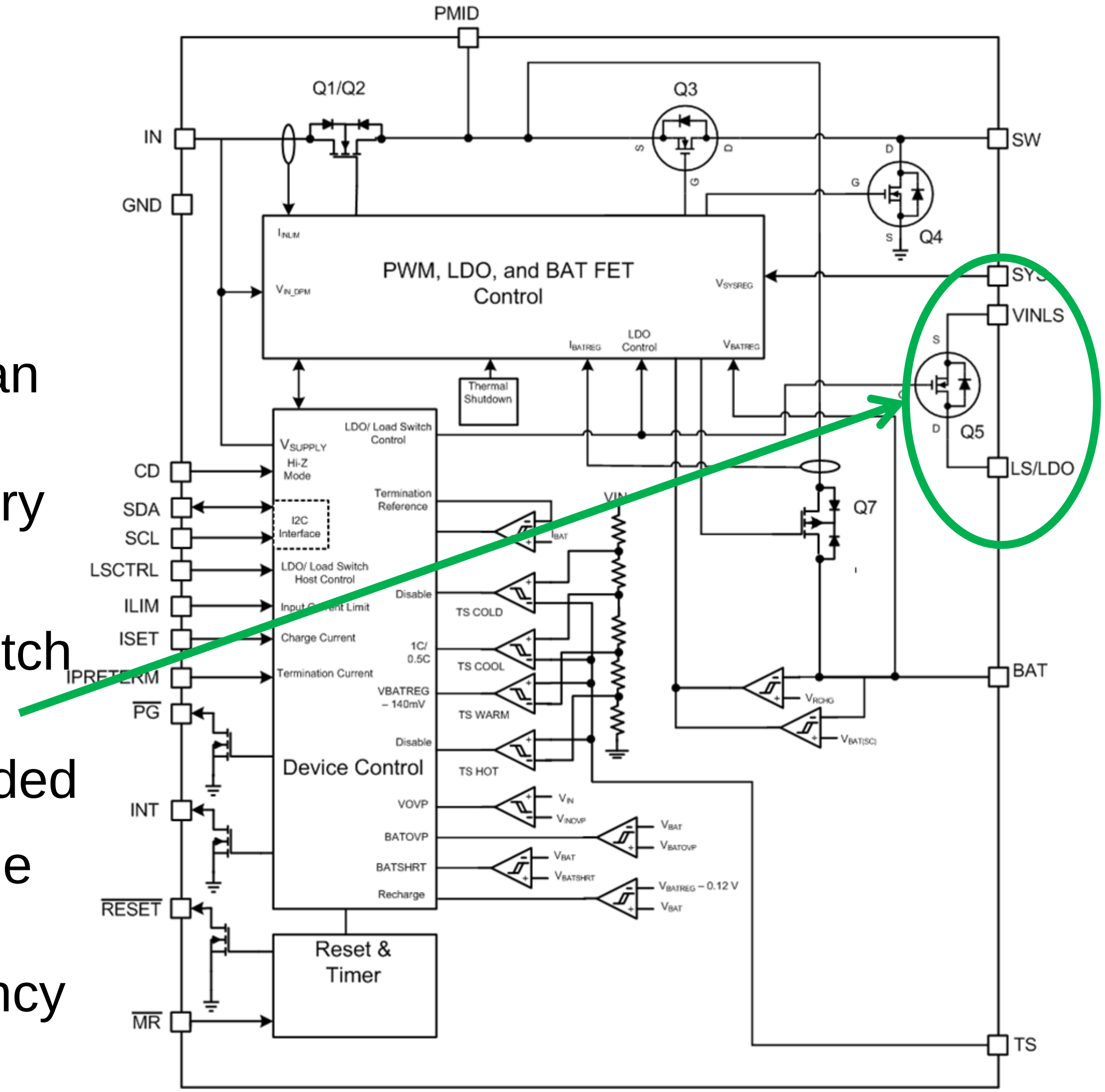
Removing boost converter leakage

TPS61046 contains an internal isolation switch to separate Vin from Vout



Low Off Current – Load Switch

- For devices that don't have load disconnect switches, a load switch can provide the same function
- Standalone load switches can be used, or they can be integrated into a larger battery management IC
- The bq25120 has a load switch that can be configured as a regulated LDO output if needed
- The input can be run from the battery, or from the DC/DC converter to optimize efficiency



Example: [bq25120]

Low Quiescent Current (I_Q)

- What is I_Q?
  - "Current drawn by the IC in a no-load and non-switching but enabled condition"
  - Current required to operate the IC (and nothing else)
  - Does not include: load/leakage on output, FB (feedback) resistor current, switching required to keep Vout in regulation, etc.
  - Not no-load input current!
  - Useful for comparing the low-power performance of different ICs
  - Not useful for estimating power drawn in your system's standby state

See *I_Q: What it is, what it isn't, and how to use it* for a thorough explanation

Buck I_Q

- Almost always drawn from Vin
- TPS62743 I_Q specification:

True I_Q (non-switching)

I_Q	Operating quiescent current	EN = V_{IN}, I_{OUT} = 0µA, V_{OUT} = 1.8V, device not switching	360	1800	nA
		EN = V_{IN}, I_{OUT} = 0mA, V_{OUT} = 1.8V , device switching	460		

IC enabled

No-load input current (IC switching)

- For a buck, no-load input current is usually slightly greater than I_Q
- Do you have no load or just a very light load (some µA or 100s of nA)?

The power of an ultra-low I_Q buck

TPS62125: 13 µA I_Q

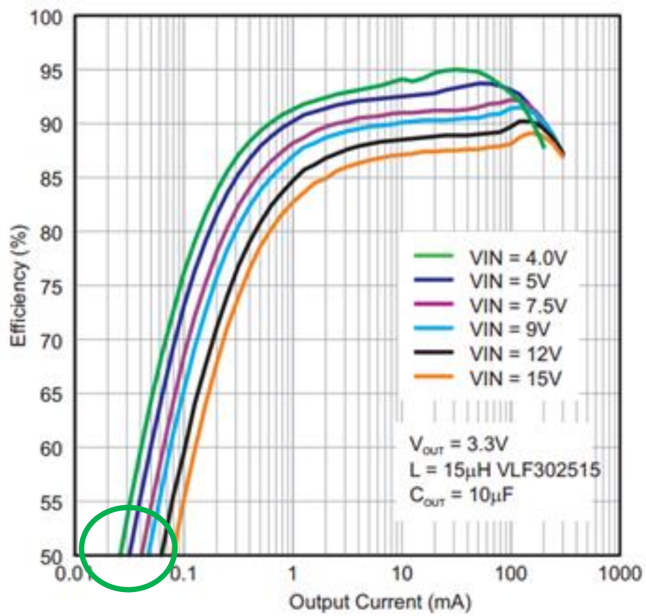


Figure 14. Efficiency vs. Output current, V_{OUT} = 3.3 V

50% efficiency at 30 µA load

TPS62743: 360 nA I_Q

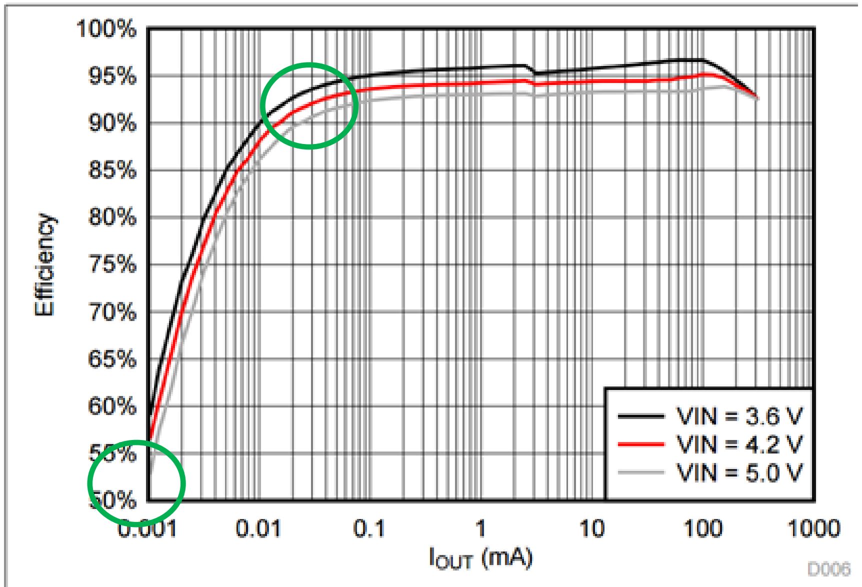


Figure 7. Efficiency vs Load Current, V_{OUT} = 3.3 V

91% efficiency at 30 µA load

50% efficiency at < 1 µA load!

Boost I_Q

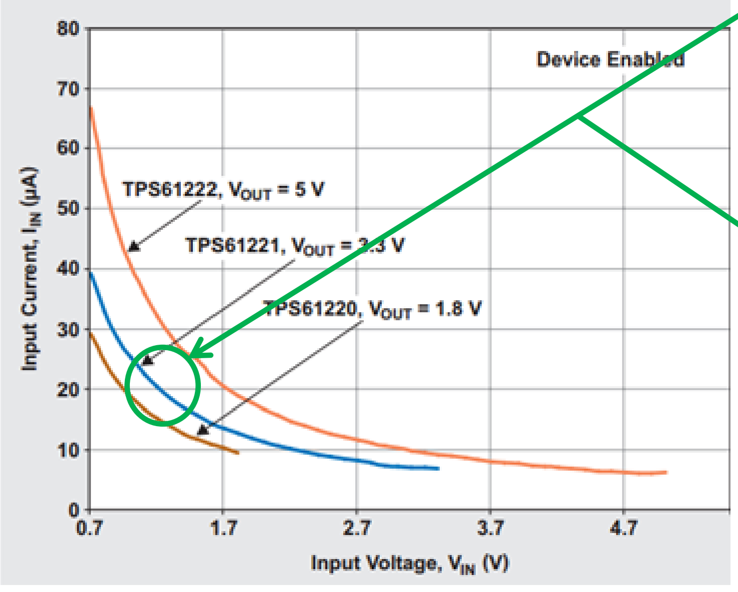
- Some drawn from Vin but usually some drawn <u>from Vout</u> as well
  - Vout's I_Q ultimately comes from Vin → creates <u>higher no-load input current</u>
- TPS61220 I_Q specification:

I_Q	Quiescent current	V_{IN}	I_O = 0 mA, $V_{EN} = V_{IN}$ = 1.2 V, V_{OUT} = 3.3 V		0.5	0.9	μA
		V_{OUT}			5	7.5	μA

IC enabled

Most current is drawn from Vout!

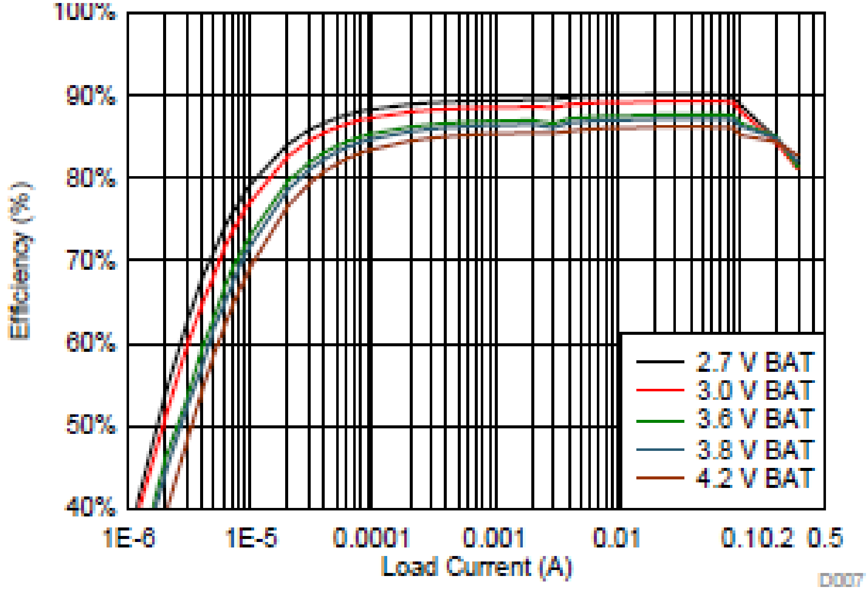
- Resulting no-load input current:



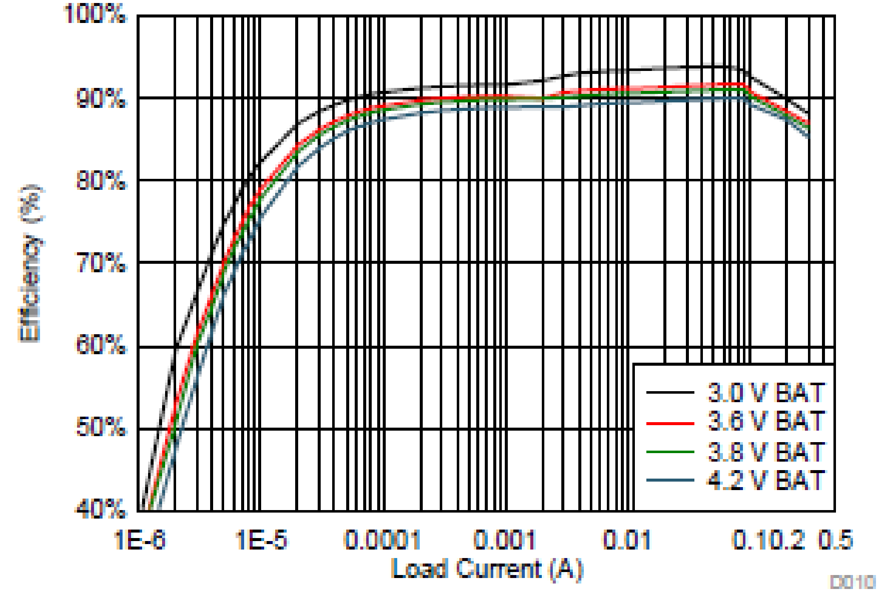
No-load input current = <u>20 μA</u>!!

High Efficiency at Full Load

- Light load efficiency is dependant on Iq and switching losses
- Full load efficiency is dependant on
  - The ratio of input and output voltages
  - The resistance of the FET from drain to source (R_{DSON}) when conducting
  - The DCR of the inductor



T_A = 25°C V_{SYS} = 1.8 V



T_A = 25°C V_{SYS} = 2.5 V

Example: bq25120 using inductor with 240mΩ DCR

Wearables Solutions Coverage

Audio Devices

- bq2510x
  Smallest Linear Charger
- TPS62743
  Smallest Low Iq DC/DC Converter

Smallest Solution IF power path and I2C configurability is not needed

Activity Monitor

- bq25120
  Meets all basic functional requirements

Smallest Solution Size and Lowest Power Consumption

Activity Monitor With Display

Activity Monitor With Display and Additional Features

- bq25120
- Add TPS61046 boost for display
- Add TPS62743 buck if needed

Most Flexible Solution

Sports Watch With Display and Full Featured

- bq25120
- Add TPS62770 for boost and buck and current sink

Smallest Solution for Full Featured Applications

bq25120: Battery Management for Wearables

Low Iq Linear Charger with Power Path Management, PWM Output, Load Switch, Voltage Based Battery Monitor, and Push-Button Reset

Features

1. Low battery current draw (Iq)

< 750nA (typ) BAT Iq with 1.8V Output Enabled
< 50nA (typ) BAT Iq in Shipmode

Low Iq allows wearables to be always-on without draining the battery. Shipmode allows shipping the device with the longest battery shelf life.

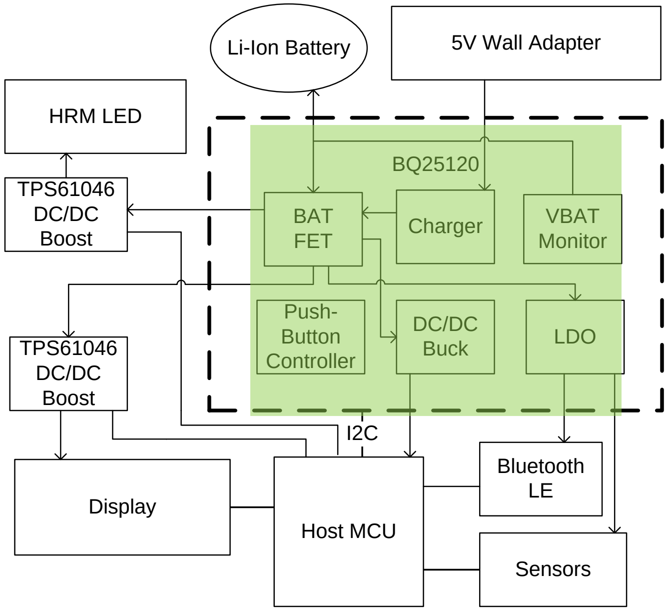
2. Small size

2.5mm x 2.5mm WCSP Package
15 mm² solution size (components)

3. Integration

Linear Charger: 300mA, 3.4V-5.5V input, 20V max
LDO: 100mA
Buck Converter: 300mA, 2.2V- 6.6V input
Power path (switcher)
Load switch
pushbutton control
battery voltage monitor: Accurate 2% VBATREG

I2C programmable flexibility to set all key parameters including ICHG, VBATREG, ITERM

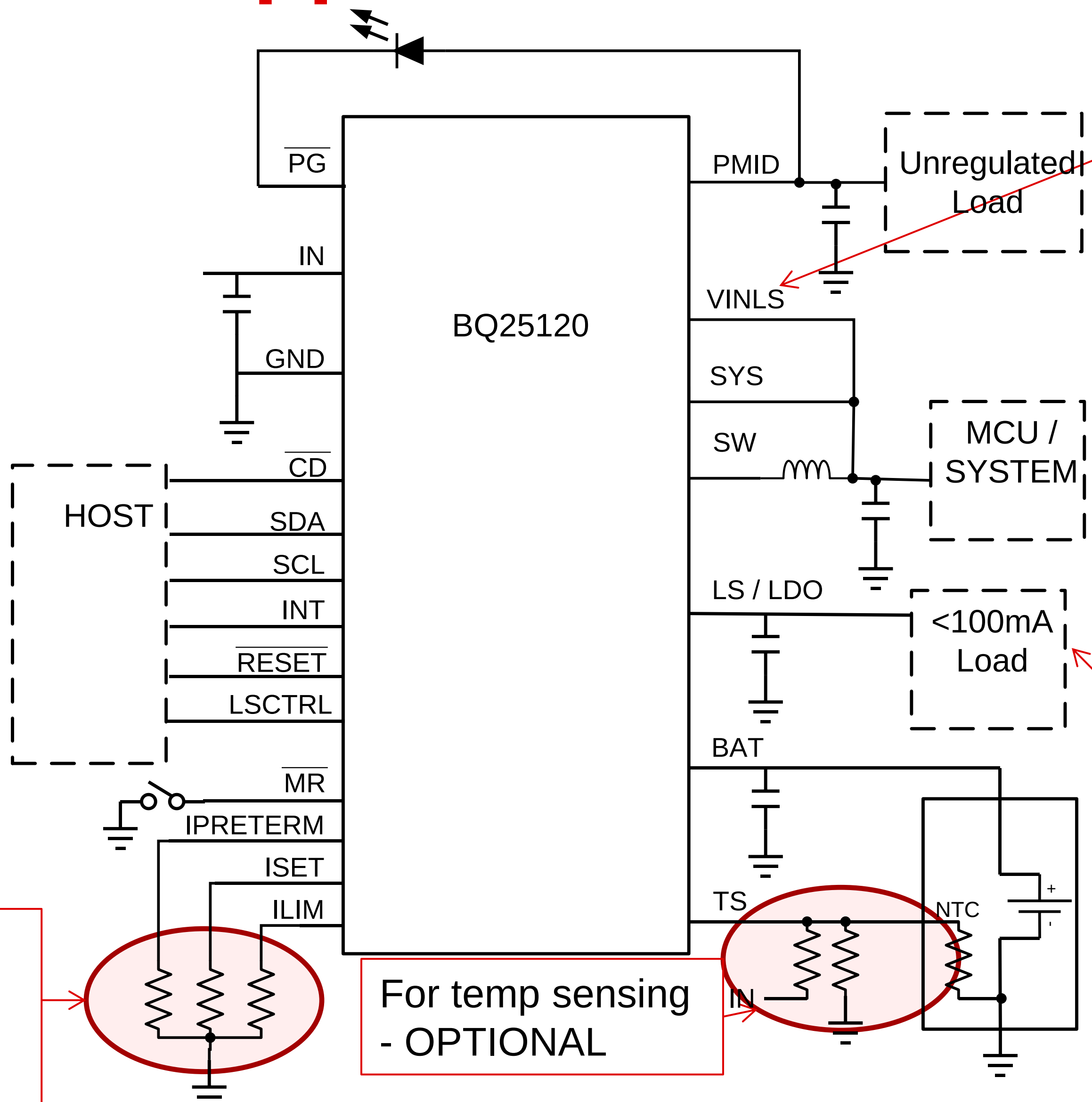


Applications

- Fitness Accessories
- Smart Watches and other Wearable Devices
- Health Monitoring Medical Accessories
- Rechargeable Toys

bq25120 – Application Schematic

HOST can control CD, ILIM, ITERM, ISET, Hi-Z, LS/LDO, SYS VBATREG, TIMER, RESET, VINDPM, SHIPMODE and see STATUS and FAULTS



Load Switch / LDO input

For Radio, Sensor, Motor or other infrequently used functions

For default and non-HOST Operation - OPTIONAL

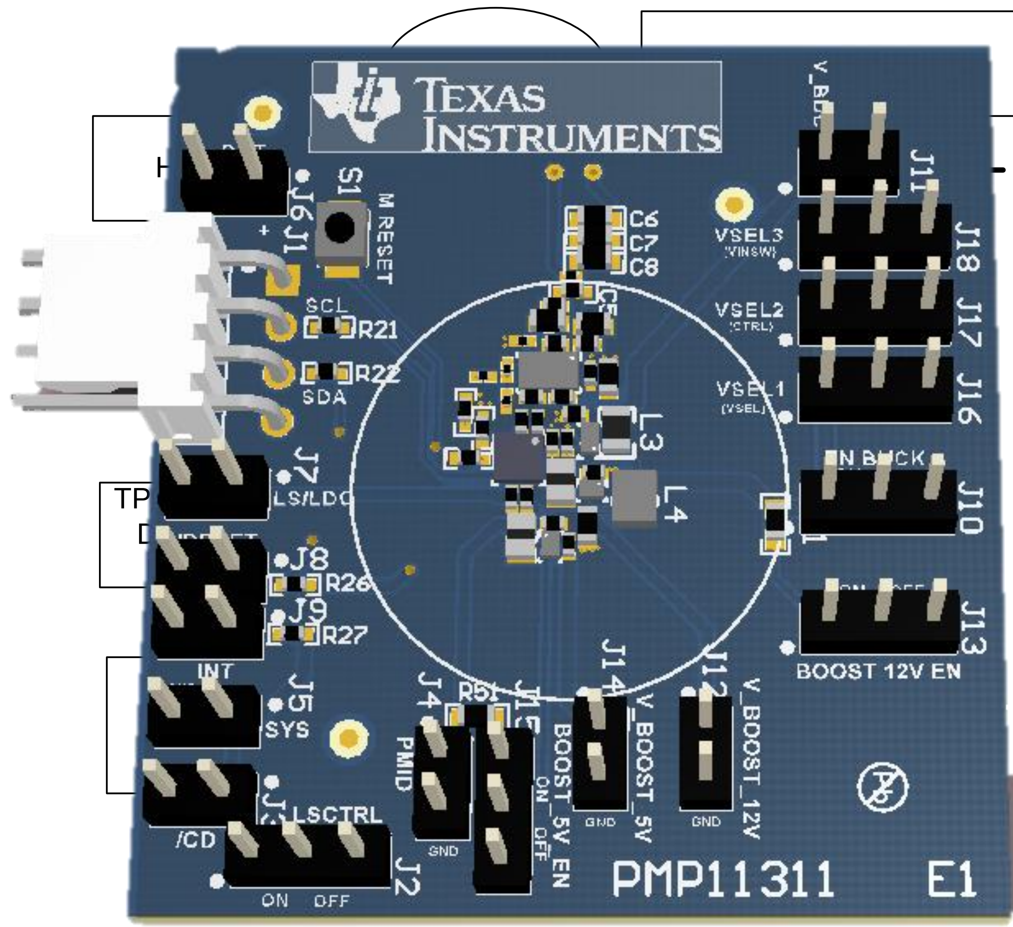
For temp sensing - OPTIONAL

Solution with bq25120 (PMP11311)

For Activity Monitor With Display and Additional Features

- bq25120
- bq51003 for Wireless Charging
- TPS61046 boost for OLED display
- TPS61240 boost for Heart Rate Monitor or LCD display
- TPS62743 buck

Most Flexible Solution



TPS62770

Tiny single-chip dual solution with 360nA Iq Buck and up to 15V Boost in WCSP

Sampling now.
RTM: March 2016

FEATURES

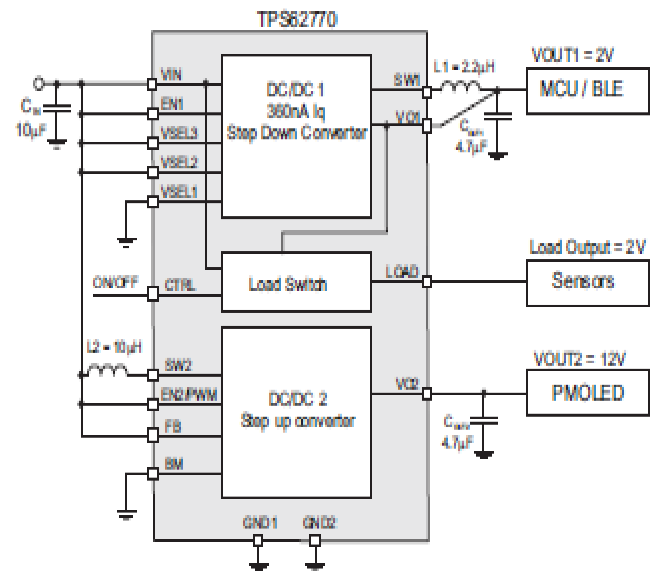
- VIN range 2.5V to 5.5V
- 1x 360nA Iq buck converter (300mA)
  - VOUT selectable with VSEL1-3
    1.0V, 1.05V, 1.1V, 1.2V, 1.8V, 1.9V, 2.0V, 3.0V
- 1 x Slew rate controlled load switch
- Discharge on VO1 / Load
- 1 x Dual mode boost converter
  - Mode selection with BM pin
  - LED current driver with PWM to current conversion (max V_{FB} voltage 200mV @ D = 100%)
  - Adjustable constant output voltage up to 15V (V_{FB} 0.8V)
- Tiny CSP16 package, 1.65mm x 1.65mm x 0.5mm, Pitch 0.4mm

BENEFITS

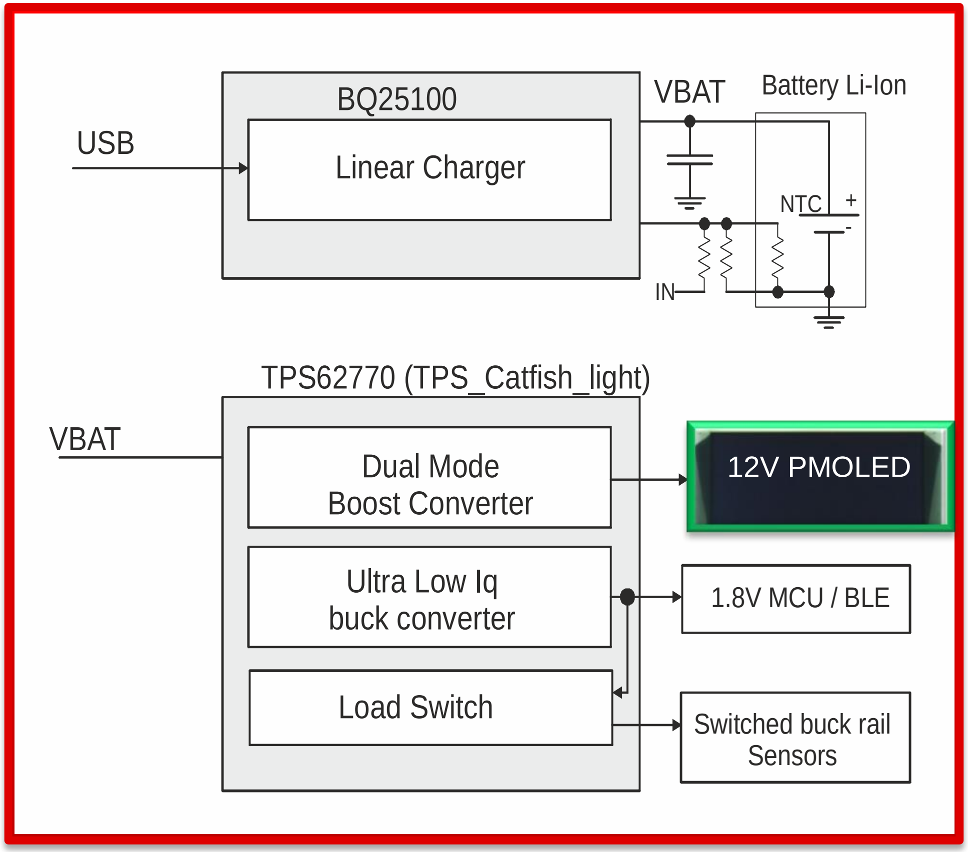
- RF Friendly DCS-Control™
- Discharge VOUT
- On board LOAD Switch to disconnect sub-system to extend battery run time
- Minimum external components to optimize board space
- Cover wide range of applications with single device
- Total solution-size: only 21mm².
  12% smaller solution compared with TPS62743+TPS61046.

APPLICATIONS

- MCU, BLE and Sensor Supply
- Wearable Electronics(HRM,PMOLED, Backlight display)
- Medical Healthcare
- Home Automation (IoT)



TPS62770 Solution 1: Powering PMOLED with BQ25100



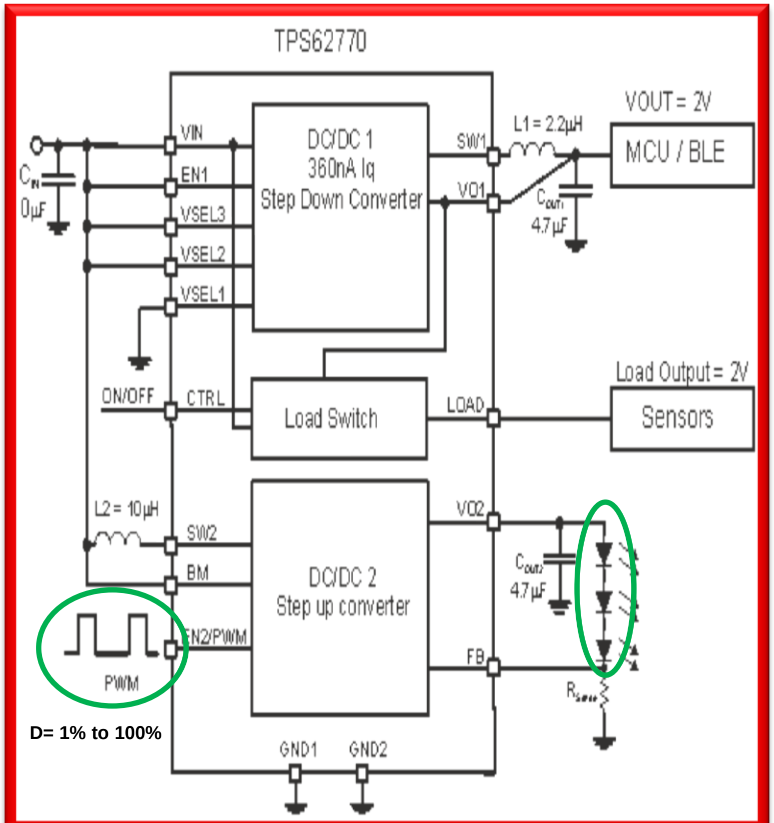
Two chip power solution without power path management:

BQ25100
(1.6 mm x 0.9 mm WCSP)

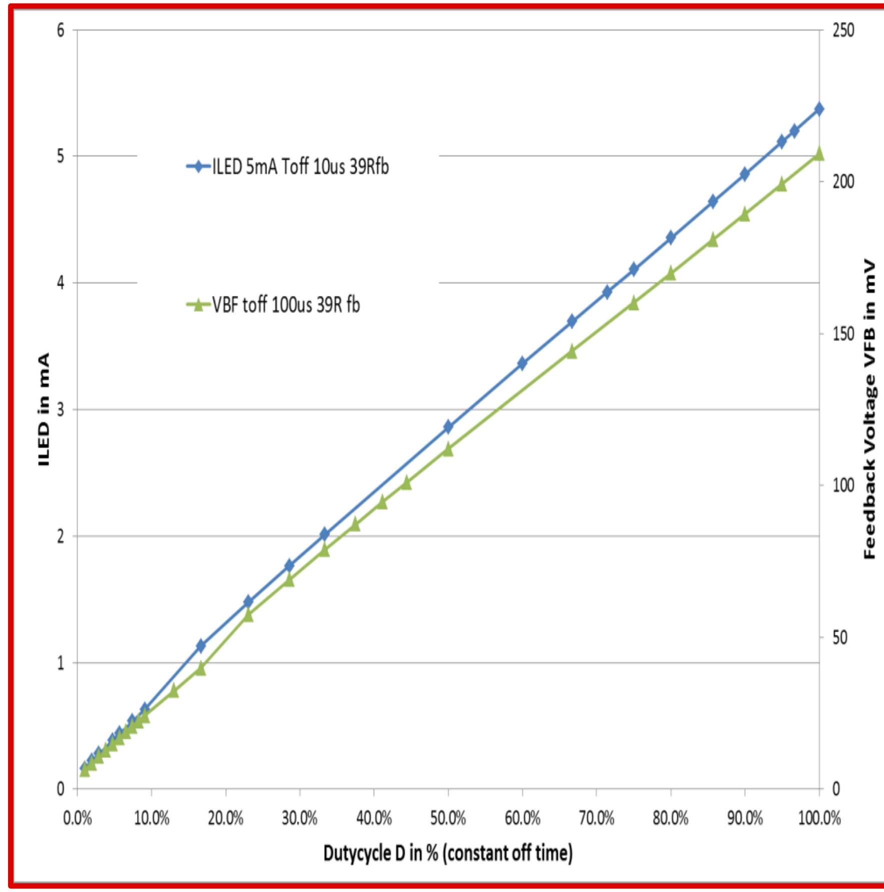
+

TPS62770
(1.65mm x 1.65mm WCSP)
Or use as standalone!

TPS62770 Solution 2: Driving LED in Series for Backlight Display



D= 1% to 100%



TPS62770 Solution 3: Driving Green LED for HRM