Power supply for remote sensors

Design considerations for electronic sensors with independent energy sources and low dropout (LDO) voltage regulators

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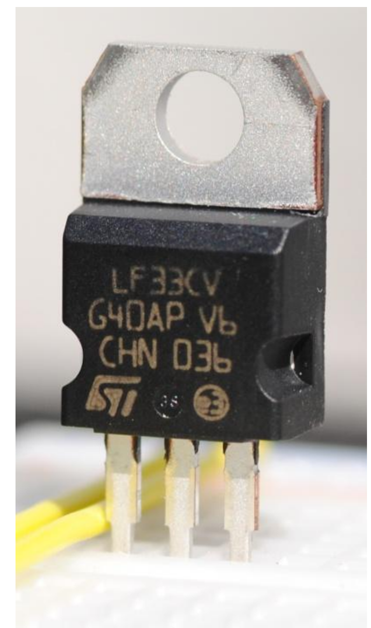
Voltage regulators overview

Many kinds of voltage regulators like the „classic“ 7805 (linear), **l**ow **d**rop**o**ut (LDO), step-down (buck), step-up (boost), switch mode power supply (SMPS), energy harvesting ICs or combinations of them

Low **d**rop**o**ut (LDO) voltage regulators are very suitable for battery power supplies due to low (quiescent) current demands and low dropout voltage



LF33CV LDO (TO-220)

Low dropout (LDO) voltage regulators

Pros:

- low dropout of voltage from the supply like primary (single-use) or secondary (rechargeable Li-Ion, NiMh) batteries
- low (quiescent) current demands, sometimes $I_q < 1\mu A$
- standard output voltages for microcontroller, sensors (1.8 volt up to 5 volt or more)
- no or very little additional (simple) parts required
- very stable (could be used as low Iq voltage reference)
- easy to get, many flavours/ packages available
- cheap
- reliable

Low dropout voltage regulators

Cons:

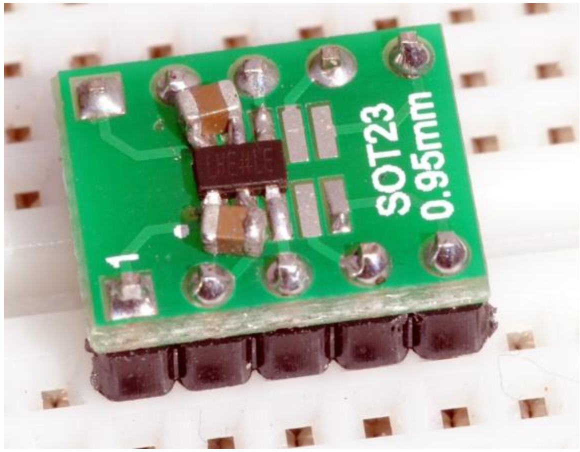
- current supply often „only“ 150 to 250mA
- ripple rejection (PSRR) not ideal (not needed in battery supply)
- not so „independent“ as energy harvesting solutions

Low dropout voltage regulators

Examples of LDOs:

- LFxxCV (xx = voltage)
- Microchip MCP170x, MCP1755
- Maxim Integrated MAX88x
- Texas Instruments TPS78x-Series
- Analog Devices ADP16x

  and many, many more...



TPS78x/ ADP16x TSOT 0.95mm pitch

LDO – design considerations

What is important when designing sensors/ microcontrollers with independent energy sources?

LDO regulator: **low quiescent current** esp. for devices with sleep mode (esp. Long periods) and **low dropout** (if fixed voltage is necessary)

Device: **sleep mode** and **power consumption when awake** (most important)

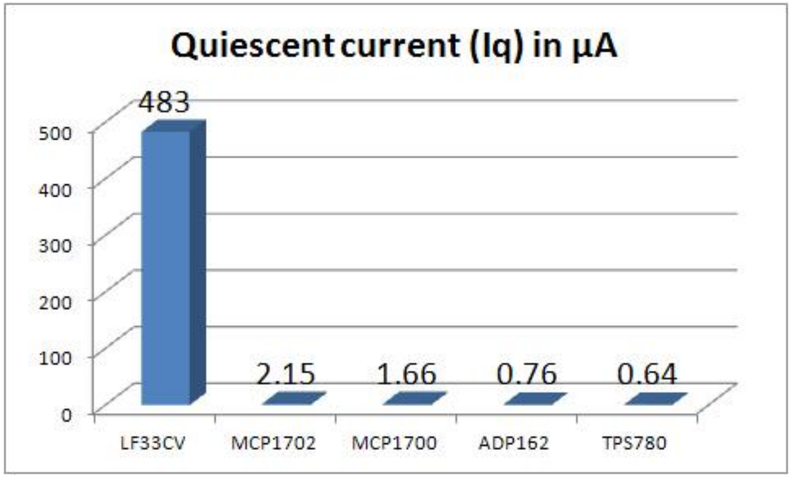
Both will rule the capacity demand of the energy source

Remote sensor case study

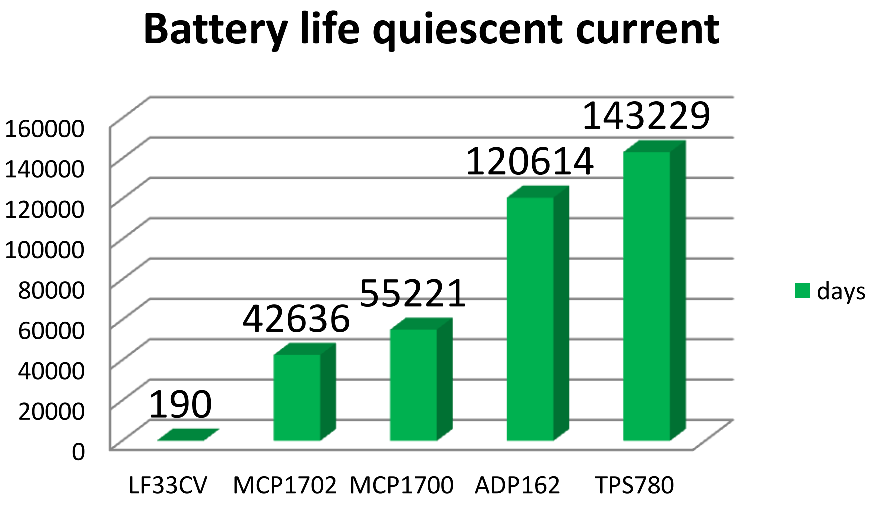
We want to design a **remote temperature sensor** with **3 AA batteries** (primary or secondary) with **3.3 V target voltage** (allowed to fall as low as 2.6V), the **temperature sensor** (TMP36) and the **transceiver** (XBee Series 2). The sensor (XBee) **awakes every 4 minutes for about 1000 ms**, sends a sample of the measured temperature (XBee ADC) and then falls back to sleep. **Power consumption when awake** about **30 mA**.

Comparison of different LDOs

Comparison of quiescent current (current consumption in sensor/ microcontroller sleep mode)

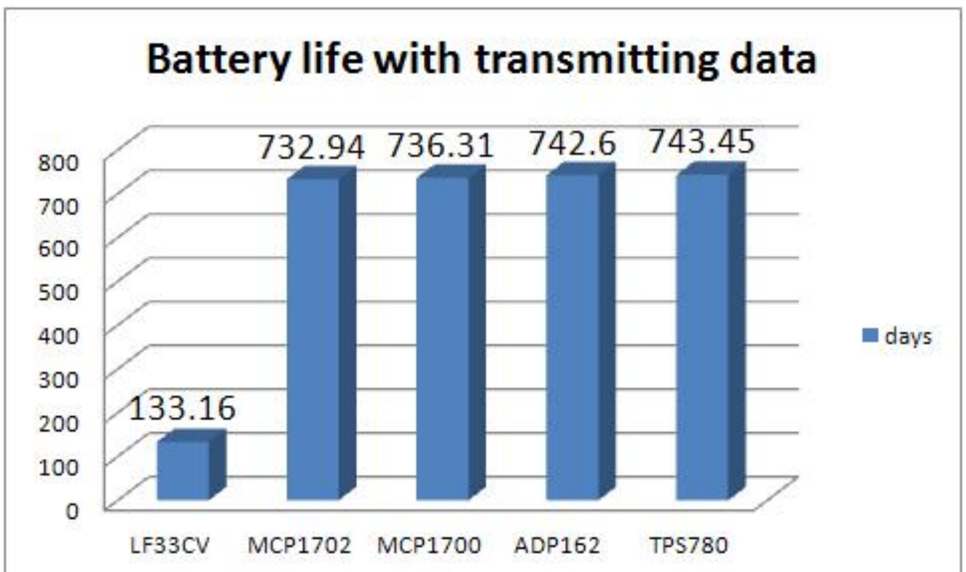


Measured values, Keithley177



Comparison of different LDOs

At first glance it looks like there are significant differences between the low Iq LDOs. But the difference is heavily dependent on power consumption when (and how long) awake. For our case:



Calculation variables:
battery capacity = 2200mAh
Iq (IC)
Iactive = 25mA
wakeups per hour = 15
duration wakeup = 1000ms

battery lifetime calculator
http://oregonembedded.com/batterycalc.htm

Energy sources considerations

Depending on the environment not all battery energy sources are equally suited.

E.g. lithium-type batteries for sensors in the field with high temperature differences and esp. low temperatures wouldn‘t be ideal. Best would be supercapacitors but for our case would not deliver enough energy.

LDO design considerations

Imax is no problem, because all mentioned LDOs have current supply of > 150mA

Package: MCP170x are SOT (1.27mm pitch)/ THT, ADP16x (TSOT 0.95mm pitch) and TPS78x are TSOT (0.95mm pitch) / SON-6 (no lead). Could be an issue

Dropout: At 30mA current consumption is 20 – 80mV (LF33CV 150-200mV). As voltage could fall as low as 2.6V no issue

External parts: All LDOs need 2x 1µF external capacitors, all **do not work without**! (except LF33CV)

Price/ availability: MCP170x cheap and easy to get (germany) other with big distributors. Prices between 50 cents and 1 Euro.

Features: all have over current limit/ over temperature shutdown. TPS78x has dual voltage

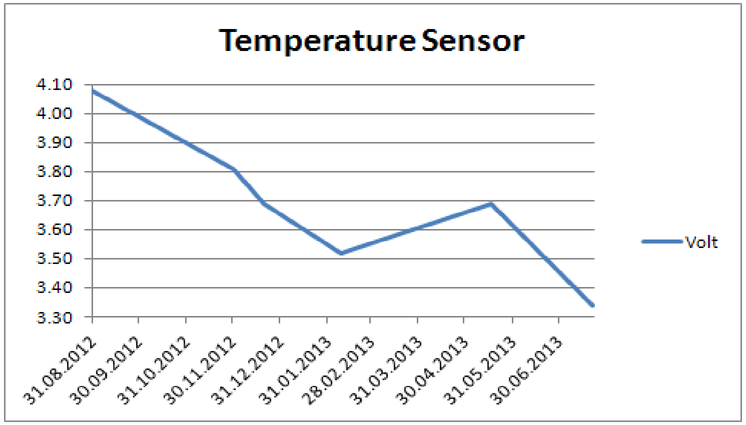
Vin max.: 5.5V up to 13.2V (MCP1702) – no concern with 3 AA (max 4.8V)

Remote temperature sensor

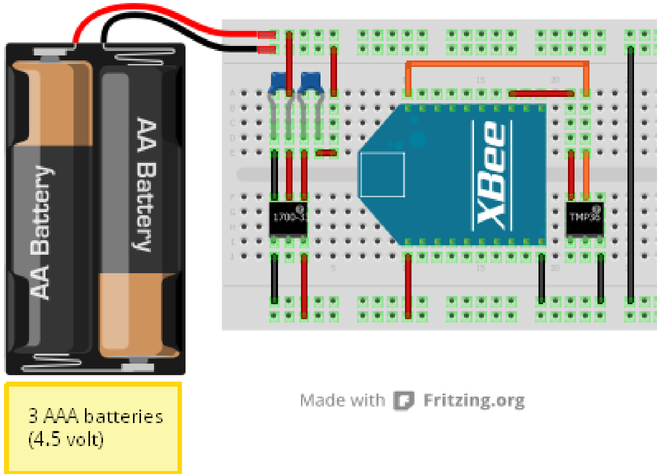
Temperature sensor with:

MCP1700 (Iq 1.6µA)
2x 1µF ceramic capacitors
TMP36
1x 1µF ceramic capacitor
XBee Series 2 (3.3V - works down to 2.6V)

Lifetime >1 year tested with 3 primary and secondary AA cells (alkaline/ NiMh (brand: eneloop))



Voltage chart from alkaline cells. The cells where already used and started with 4.1V and lasted about 1 year



Energy harvesting ftw

* More independent than battery sources and best suited for very remote/ and or multiyear maintenance-free sensors. Environment-friendly

* Needs (much) more design considerations

* Multiple energy sources possible (photovoltaic, TEG, piezo...)

* Very intelligent ICs available (e.g. from Linear Technology LTC31xx)

Thank you!

Links:

Battery lifetime calculator: http://oregonembedded.com/batterycalc.htm

TPS78x (Texas Instruments): http://www.ti.com/product/tps78001

ADP16x (Analog Devices): http://www.analog.com/en/power-management/linear-regulators/adp160/products/product.html

MCP1700 (Microchip): http://www.microchip.com/wwwproducts/Devices.aspx?dDocName=en010642

MCP1702 (Microchip): http://www.microchip.com/wwwproducts/Devices.aspx?dDocName=en028178

LF33CV (STMicro): http://www.st.com/web/en/catalog/sense_power/FM142/CL1015/SC312/PF63606

Energy Harvesting (Linear Technology): http://parametric.linear.com/Energy_Harvesting

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