How nanoPower Technology Increases Sensor Lifetime and Performance

Training and Technical Support Team
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Agenda

- Introduction
- Batteries
- Battery interface device
- Supervisors/voltage monitors
- DC-DC converters

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How nanoPower Technology Extends Battery Life for Compact Designs

Gas/Water Meters

Service/maintenance call costs are many times those of the battery cost

Insulin Pump/Wearable Medical

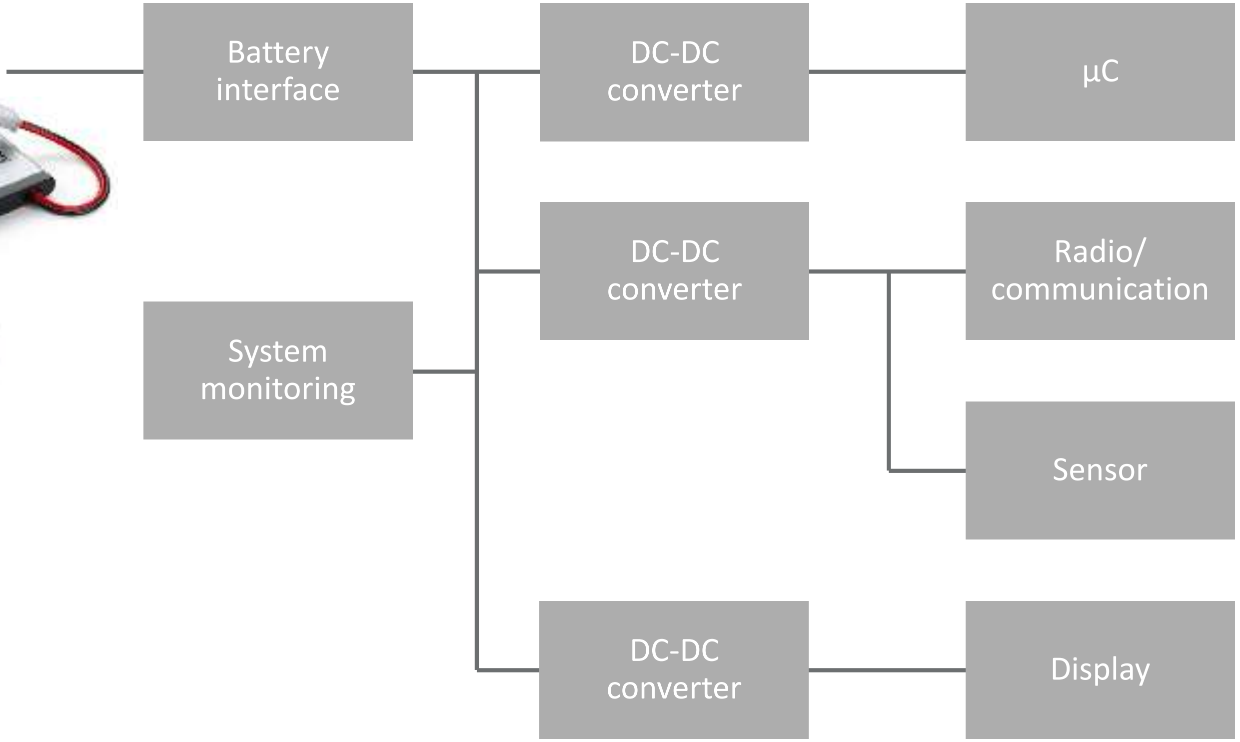
I hope it works – it is important that it does…seriously!

CO2 Detector/Smoke Detector

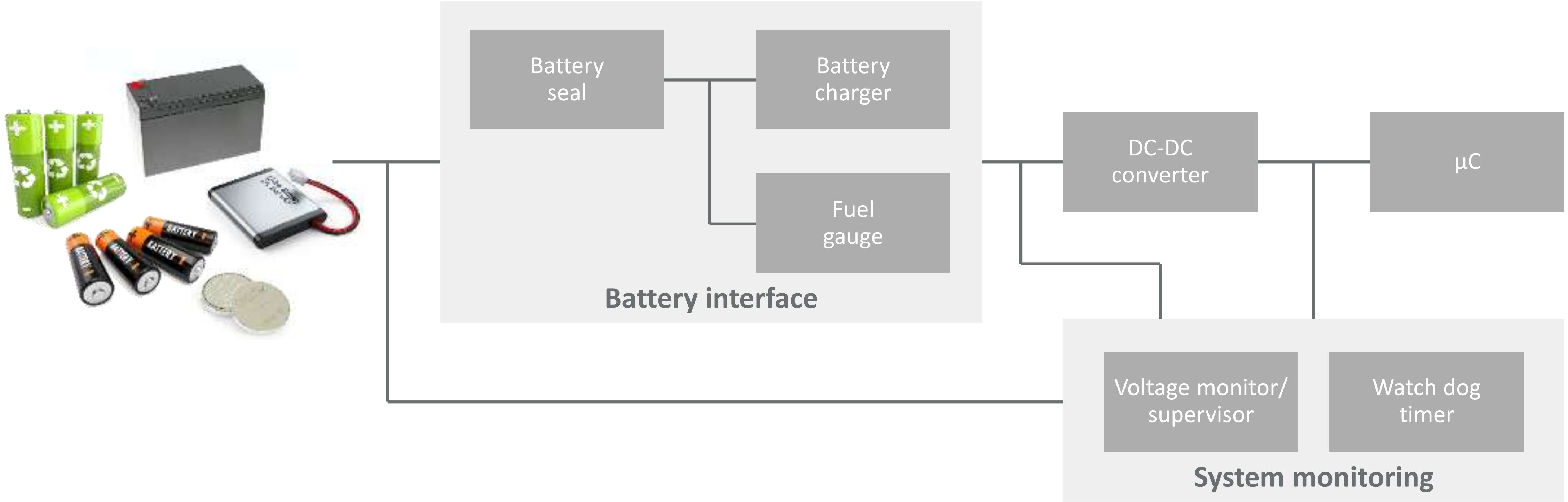
Picture doing this every 1-2 months!

nanoPower technology is the key to maximizing battery life while achieving all key product features and quality

Basic Building Blocks of a nanoPower System



The Role of Batteries in Sensor-based Designs



Example #1: Alkaline Batteries – The Most Ubiquitous

Design challenges:

- Min operational voltage < 1V
- >500mOhms DC resistance in temperature

Classification	Alkaline
Chemical System	Zinc-Manganese Dioxide (Zn/MnO_2) No added Mercury or Cadmium
Designation	ANSI-15A, IEC-LR6
Nominal Voltage	1.5 volts
Nominal IR	150 to 300 milliohms (fresh)
Operating Temp	-18°C to 55°C (0°F to 130°F)
Typical Weight	23.0 grams (0.8 oz.)
Typical Volume	8.1 cubic centimeters (0.5 cubic inch)
Jacket	Plastic label
Shelf Life	10 years at 21°C
Terminal	Flat contact

Typical discharge characteristics at various power drains

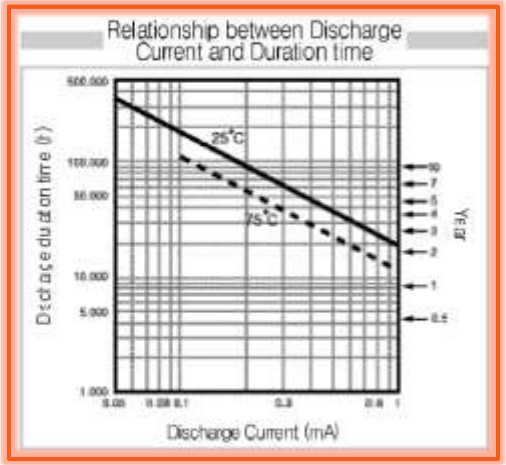
All testing at 21°C (70°F)

Example #2: Battery Optimized for Longest Lifetime (>= 20 Years)

E.g. Lithium thionyl chloride batteries

Why?

- High specific energy
  - > Typical D cell nominal capacity is 19Ahr
  - > But… decreases with high temp to ~12Ahr @ 75°C
- Low self-discharge rate/long service life
  - > 1% after 1 year at 20°C
- Wide operating temperature
  - > -55°C to 125°C



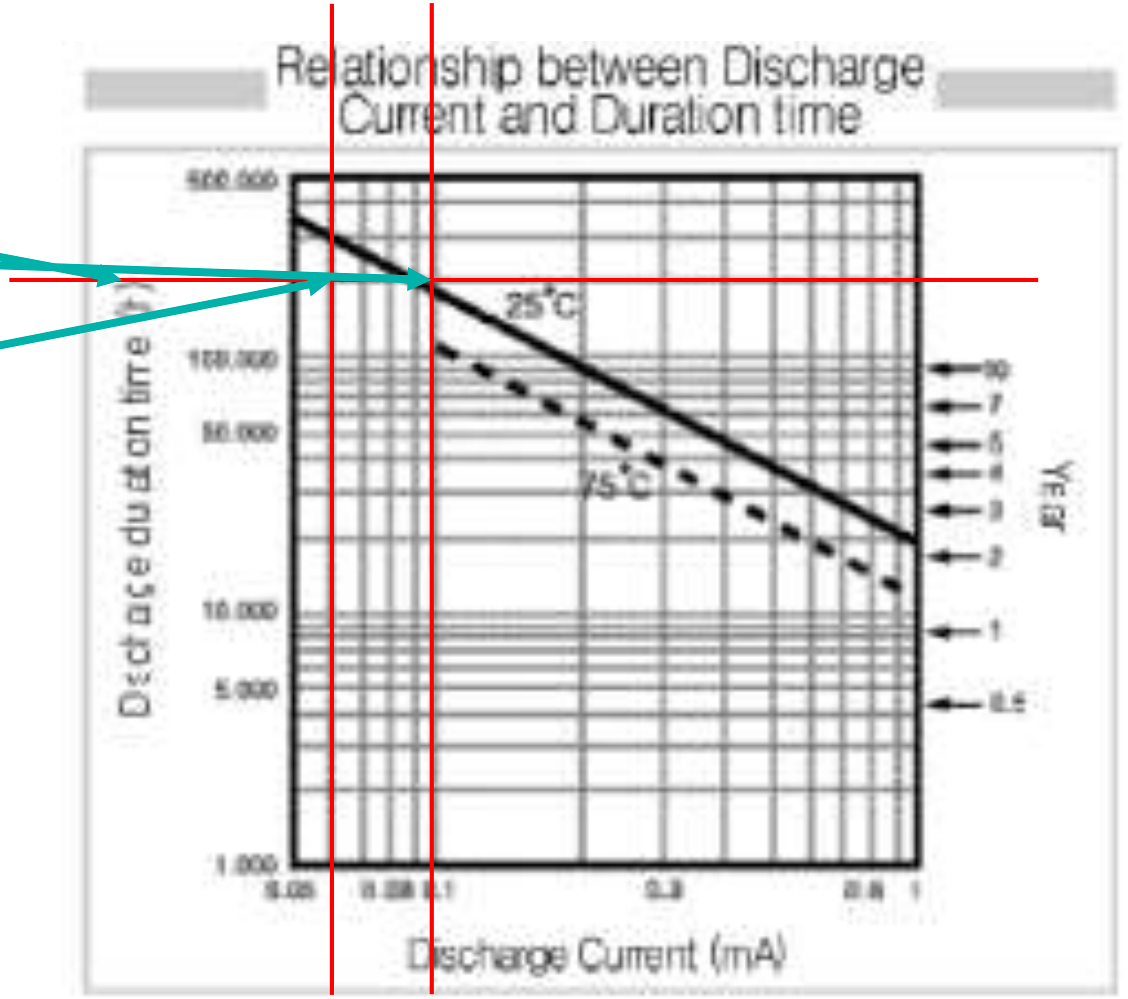
Specifications	
Nominal voltage	3.6V
Nominal capacity (at 4mA, +20˚C, 2.0V cut off)	19,000mAh
Max. continuous discharge current (to get 50% of the nominal capacity, +20˚C, 2.0V cut off)	100mA
Max. pulse discharge current	250mA
Weight	100g
Operating temperature range	-55˚C ~ +85˚C
Reaction surface area	$40cm^2$
IEC	ER32L615

Key Characteristics
ISO9001, 2000 approved
Low self discharge rate (less than 1% after 1 year of storage at +20˚C
Hermetic glass-to-metal sealing
Non-flammable electrolyte
U.L. recognized (file number MH18384)

Example #2: Battery Optimized for Longest Lifetime (>= 20 Years)

Sample calculations for D cell

- 20 years = 175,200 hr.
- Average current draw at 25°C = 108µA
- Average current draw at 75°C = 65µA
  - Sleep current has been quoted as 11µA
- PA calculation
  - 1A for 1 sec every 4 hours = 70µA average



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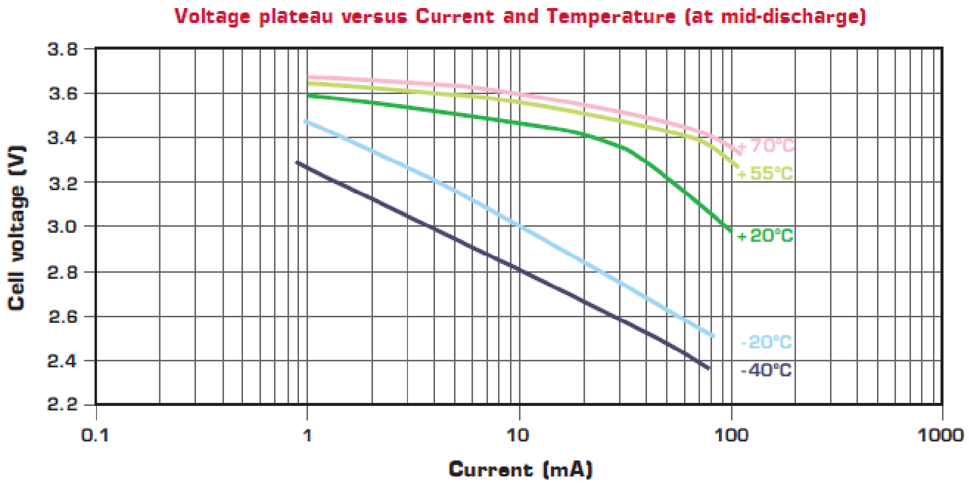
Example #2: Battery Optimized for Longest Lifetime (>= 20 Years)

What are the disadvantages?

- Low maximum pulse discharge current
  - > 250mA
- High output impedance (same thing)
  - > Old and cold output impedance can be as high as 50 ohms for a D cell!
  - > >50mA collapses the battery



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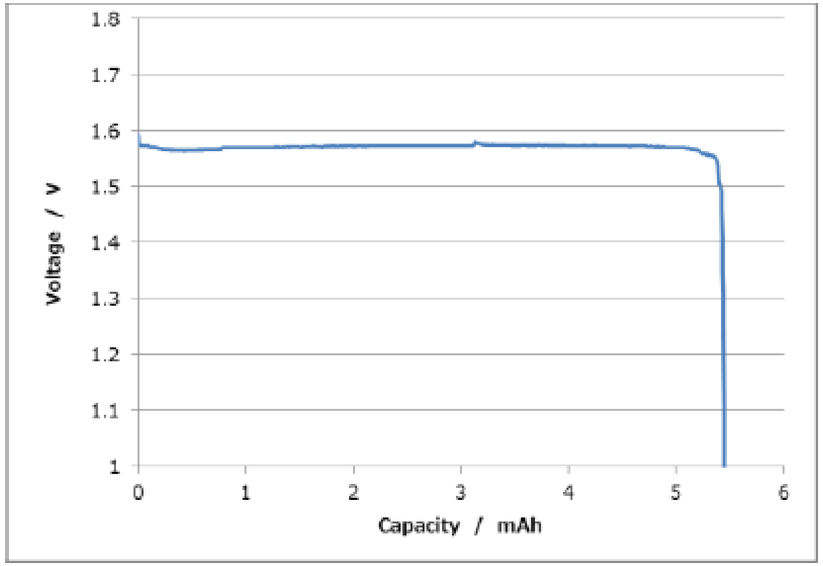
Example #3: High Capacity With Small Size – Silver Oxide

Battery characteristics

- Higher runtime than Li-ion
- Flatter discharge curve than alkaline
- Higher voltage (1.55V) than Hg batteries



Circuit implications

- Need minimum start voltage <1.5V
- Power can be optimized for narrow operating range
- Early detection of battery failure requires high precision in voltage monitoring

Example #4: Li-Ion Rechargeable Batteries

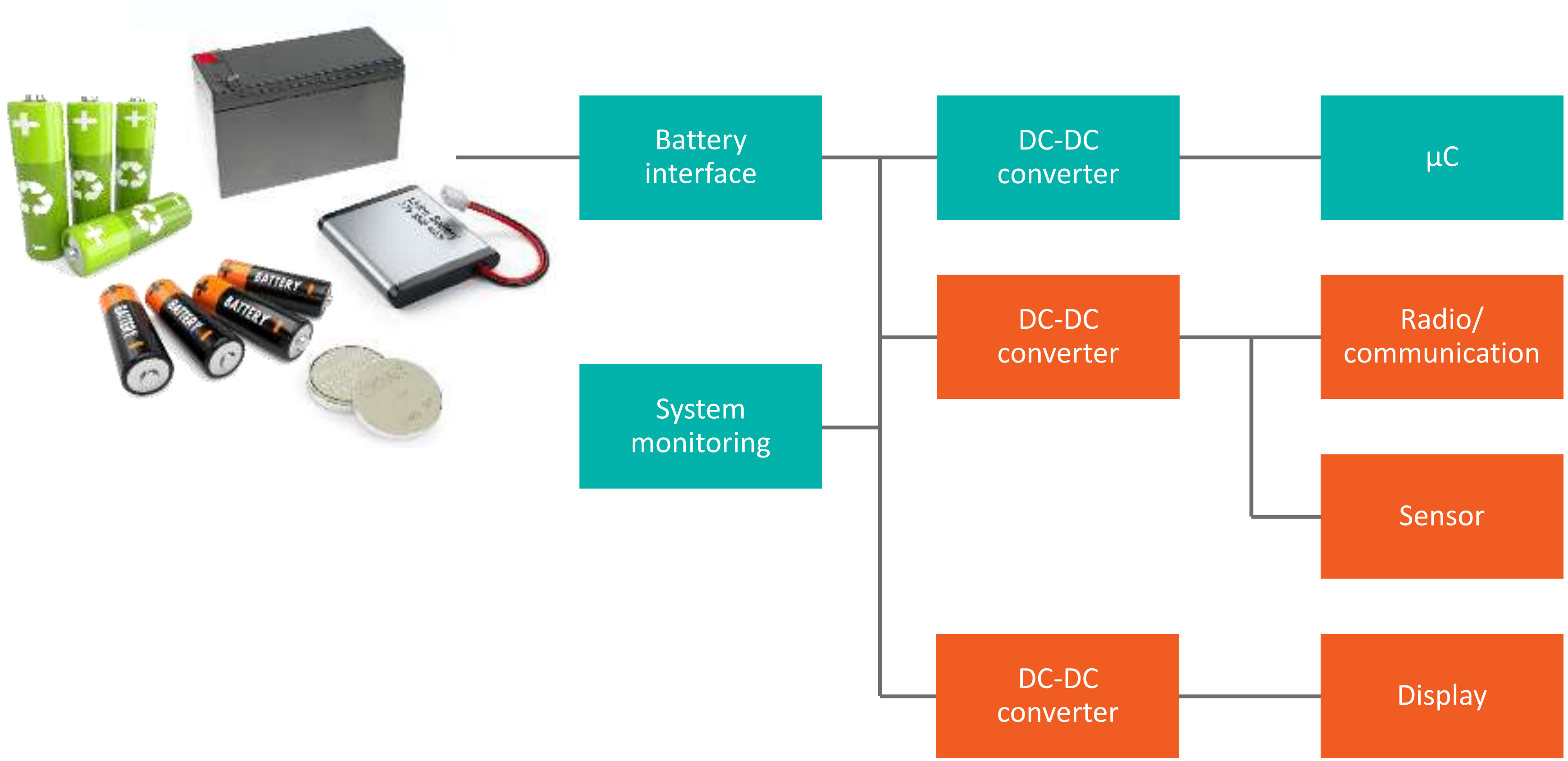
Battery characteristics

- V_{BATT} → 2.7 to 4.375V
- Battery safety risk at high temperature
- Charging and discharging profile affect battery lifetime
- High current capability

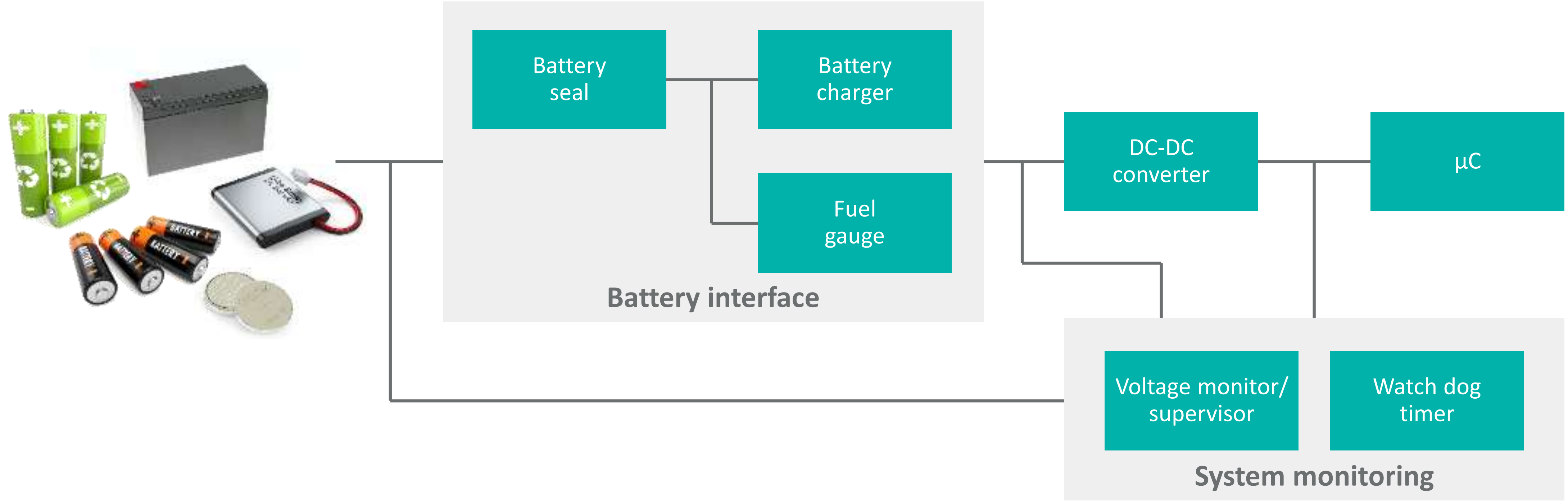
Circuit implications

- DC-DC converter optimized for wide power input range of operation
- Need dedicated fuel gauge function to monitor battery health
- Need dedicated charger and access to battery periodically

Always-on Functions vs. On-demand Functions

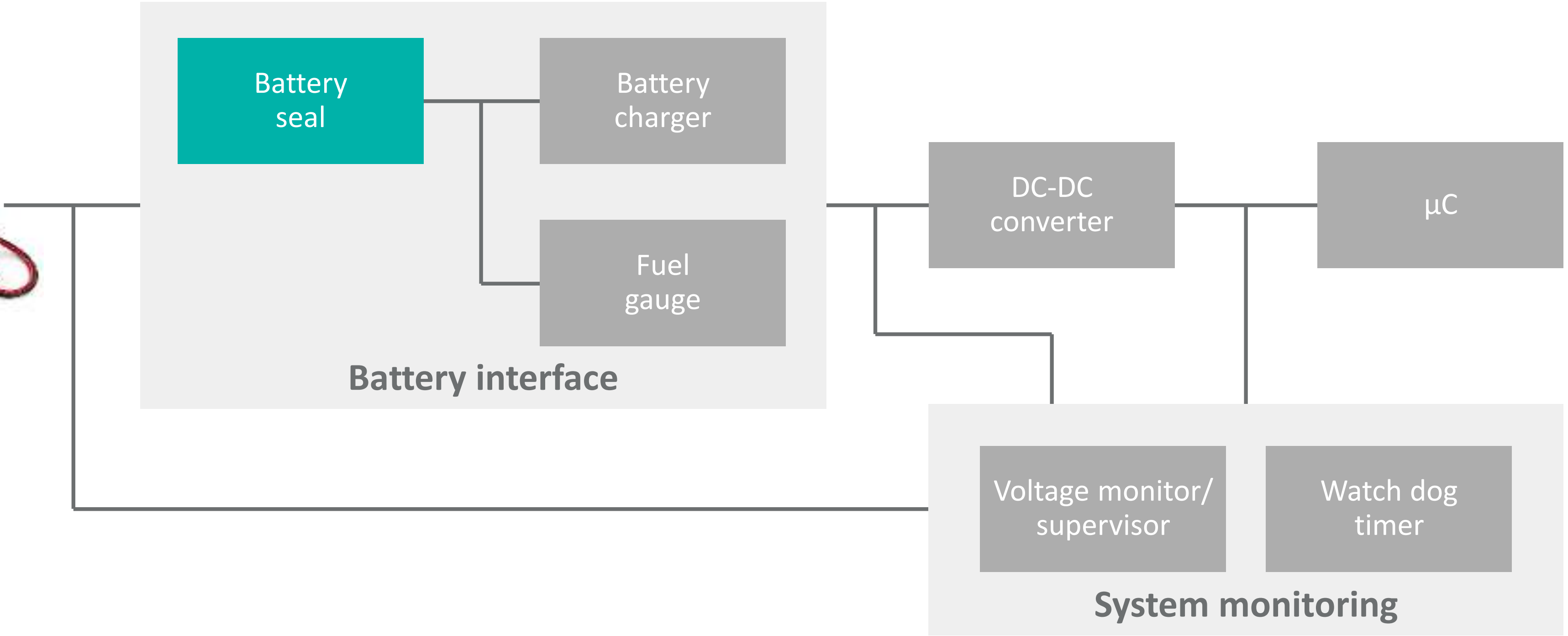


Expanding the Always-on Circuits



Battery Seal – Push-button Controllers

Battery seal improves ship-mode battery life,
especially in non-rechargeable applications

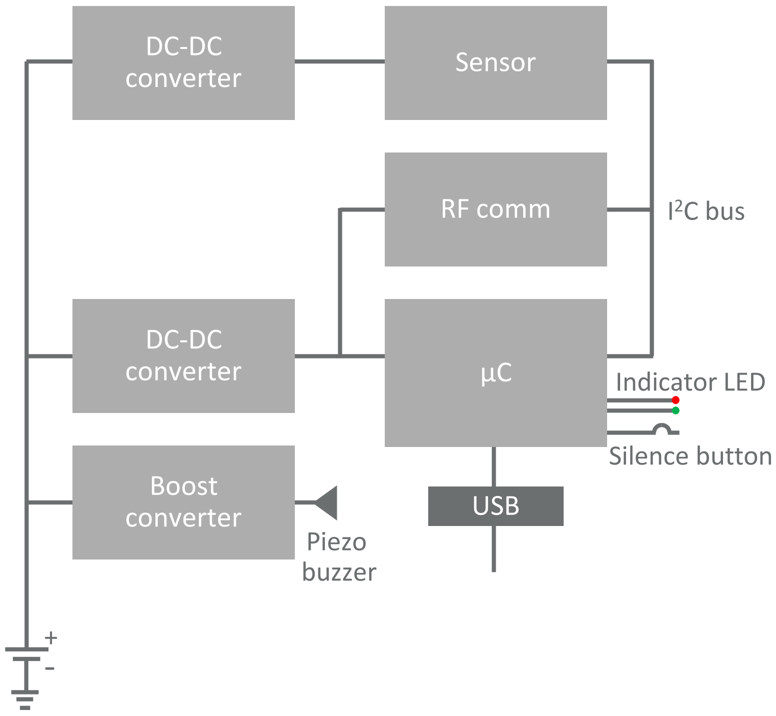


For push-button applications, MAX16150 consumes 20nA I_Q – industry's lowest

Ship Mode/ON-OFF IC Use Case

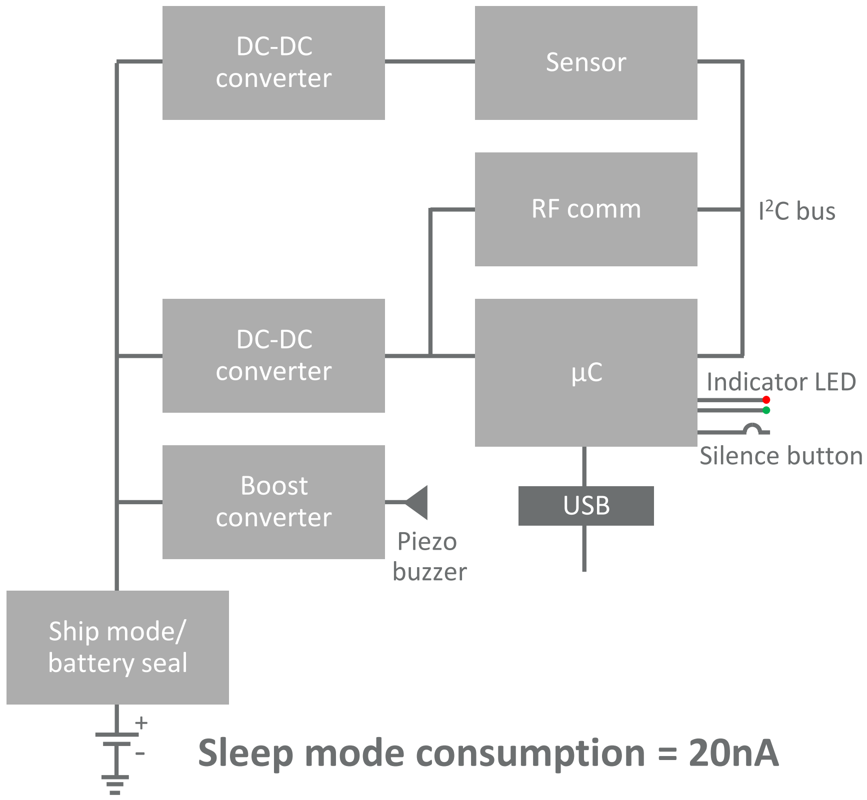
Example: CO_2/smoke detector

Without battery seal/ship mode



Sleep mode consumption = 1.2µA

With battery seal/ship mode



Sleep mode consumption = 20nA

Extends battery life by 30%

Key Considerations for Battery Seal Design/On-off Design

Requirements

- Standby current/shutdown current
- Small size
- System interrupt mechanism

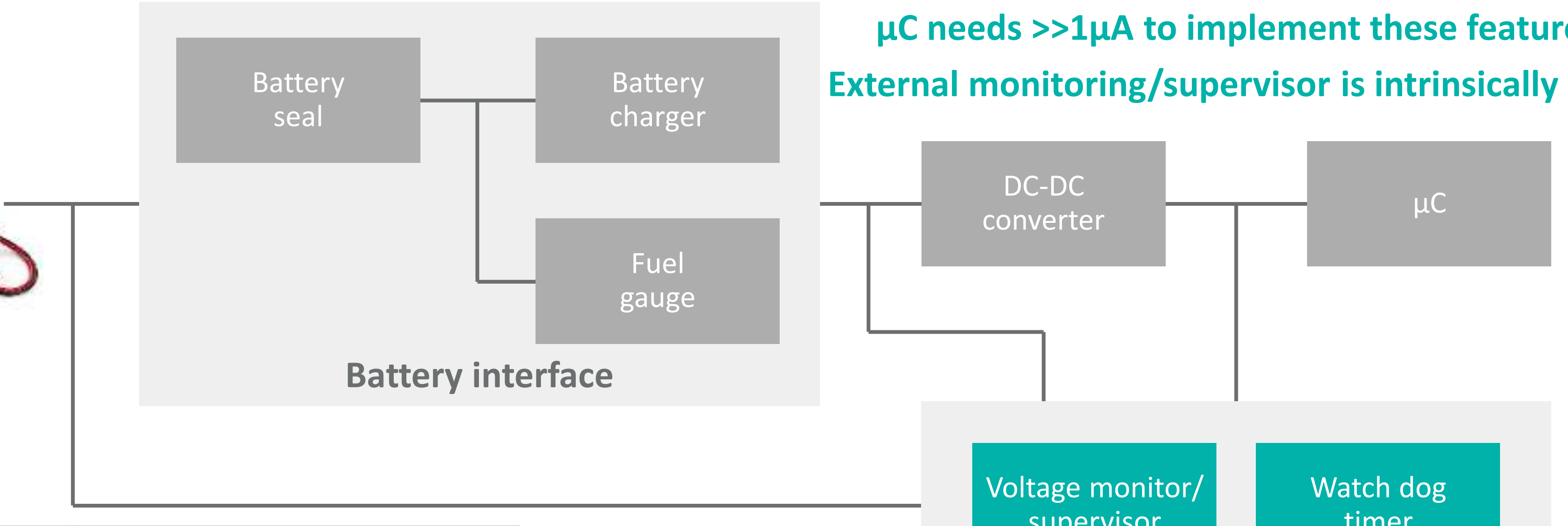
Maxim solution

- Standby current → 20nA across temp
- 6-bump WLP/SOT23-6
- Integrated one-shot interrupt generation

System Monitoring: WDT, Supervisor

µC needs >>1µA to implement these features

External monitoring/supervisor is intrinsically safer

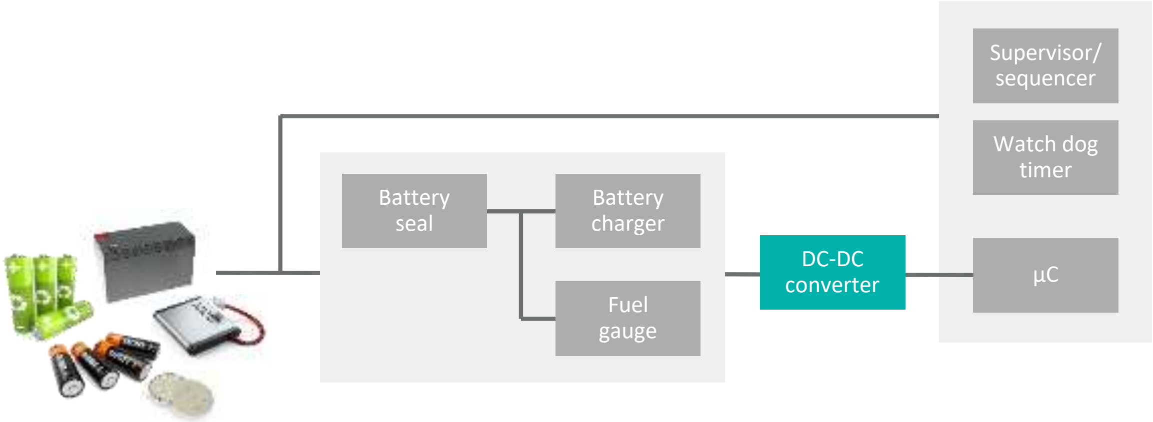


MAX16056/59	125nA I_Q supervisor with WDT and MR
MAX16152/55	400nA I_Q supervisor with WDT and MR
MAX16140	370nA I_Q supervisor with MR
MAX16072/74	4-bump supervisor with 700nA I_Q
MAX31341B	nanoPower RTC

Making the Case for nanoPower Supervisors/WDT

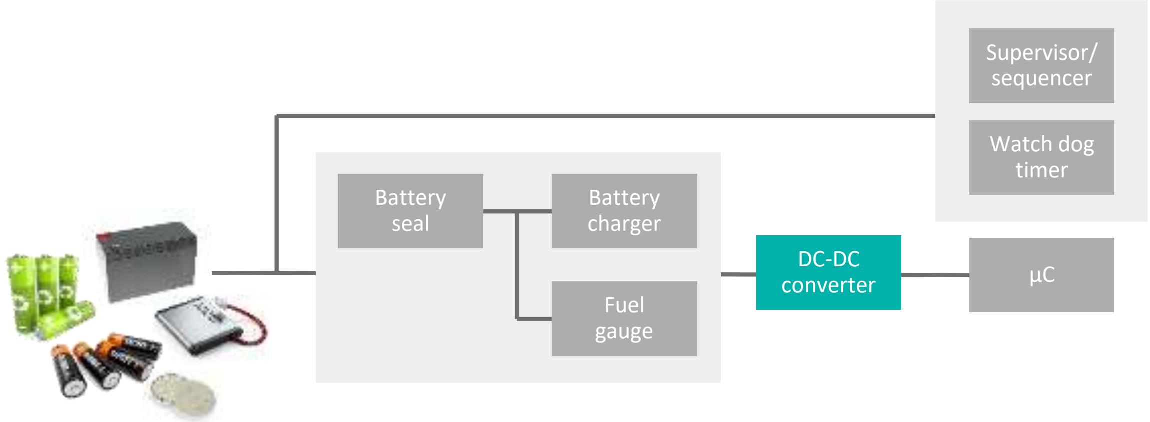
Example: Fitness watch

µC with integrated WDT/supervisor function



- Need specialized micro → 5µA to implement all functions in a µC
- Diagnostics not robust → micro checking itself as opposed to second layer of protection

With separate WDT/supervisor functions



- Simple Arm® M0 is enough – µC no need for low power
- Micro diagnostics works even if micro fails
- Intrinsically robust

Simplifies overall µC requirements and I_Q consumption

Key Considerations for Supervisor Products

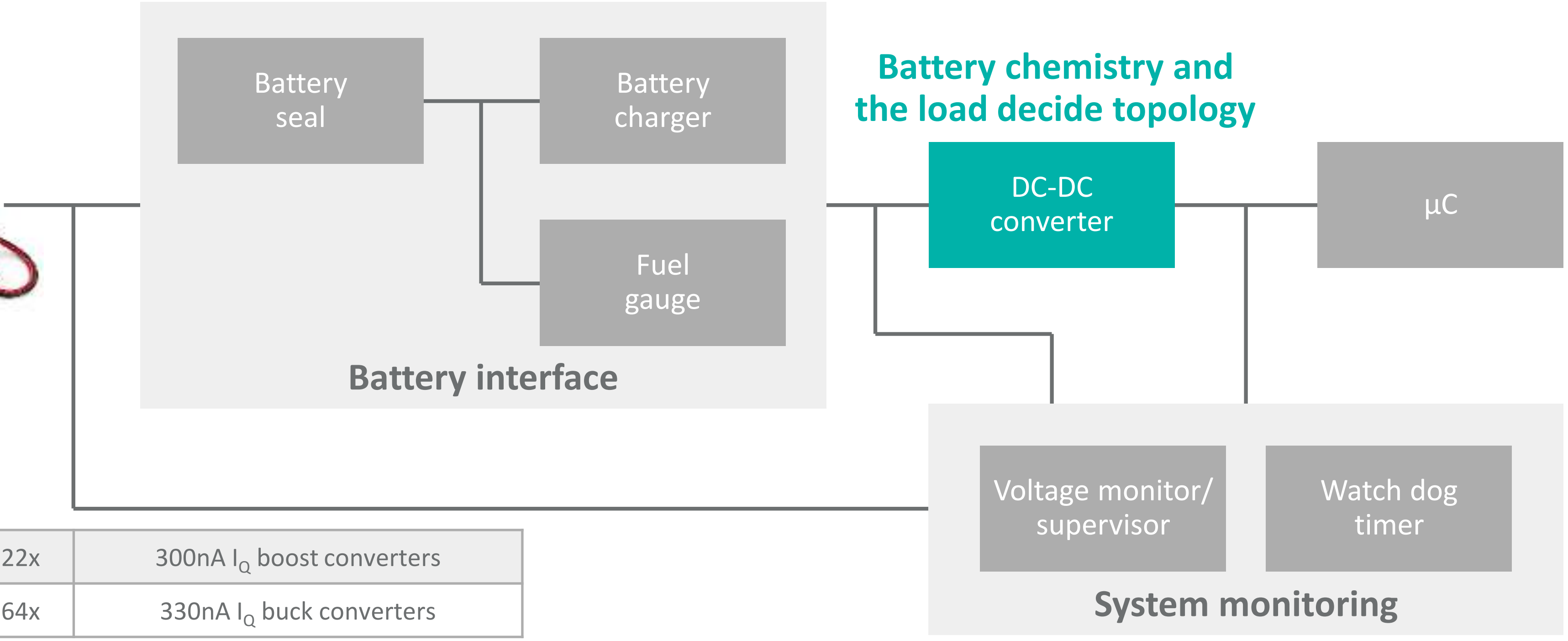
Requirements

- Low I_Q
- Accuracy
- Small size

Maxim solution

- I_Q → 125nA
- Accuracy → 1%
- 4 pin/6 pin WLP, SOT23-6, uDFN

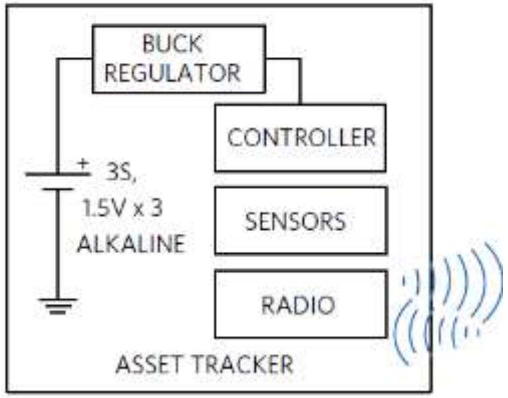
DC-DC Converter



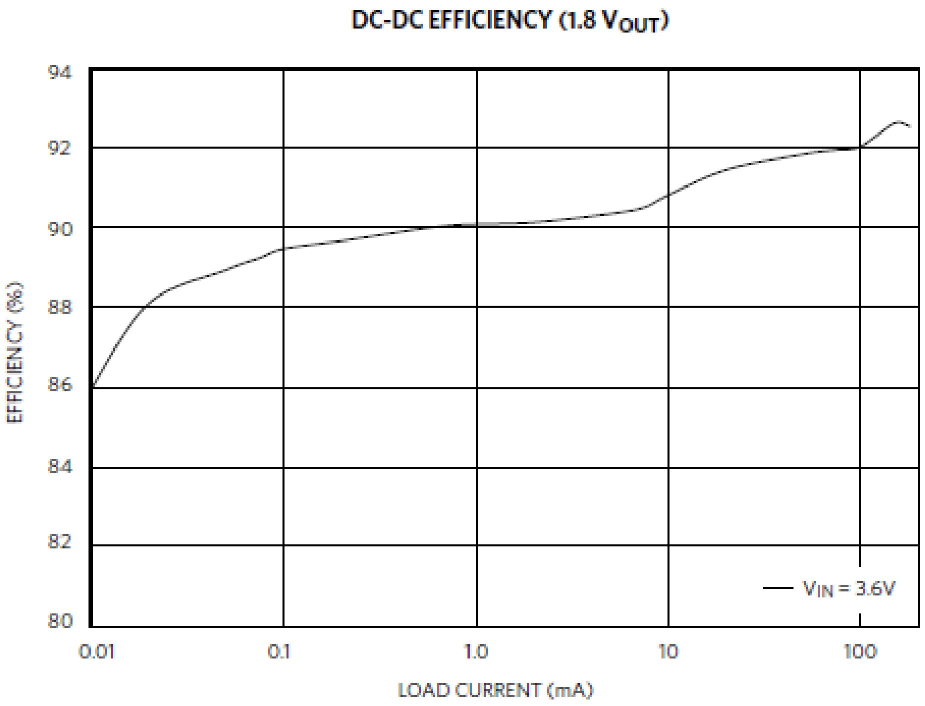
MAX1722x	300nA I_Q boost converters
MAX3864x	330nA I_Q buck converters

nanoPower DC-DC Use Case

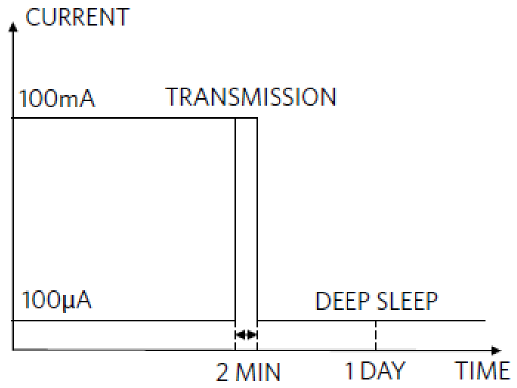
Example: Asset-tracking beacon



Block diagram



Efficiency → >86% @ 10µA



Load profile

Over 20% improvement in battery lifetime over a system with 4µA of I_Q

Key Considerations for nanoPower DC-DC Converters

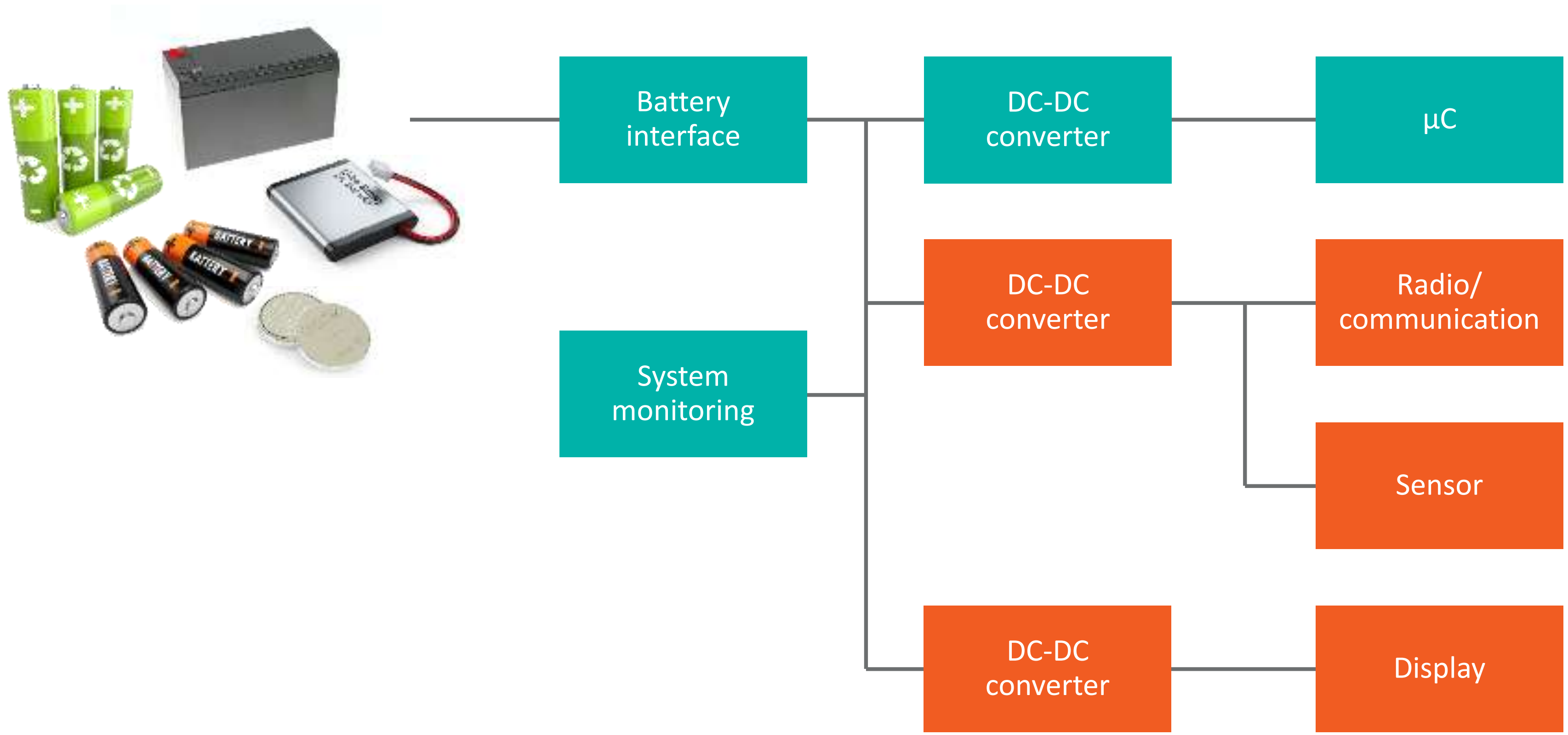
Requirements

- Fast transient response out of nanoPower mode (transient undershoot/sag)
- Small size
- Efficiency @ 10-500µA load as opposed to efficiency @ 100mA load

Maxim solution

- <3% transient sag
- 6-bump WLP, 2 x 2 uDFN
- 88% efficiency @ 10µA, >90% efficiency for >15µA

Considerations for On-demand Circuits



Key Considerations for On-demand Power Conversion

Requirements

- Low shutdown current
- Good full-load performance
  - > Noise, PSRR, transient response, dropout for LDO, size
  - > Medium-to-full load efficiency, transient response, ripple, size
- Programmable/fast startup

Maxim solution

- ISHDN → <1nA
- >70dB PSRR
- <5µV noise, 50mV dropout, programmable soft-start, 6-bump WLP
- >90% efficiency, small size, soft-start, 6-bump WLP

Keeping Circuits Always-on

Advantages

- Some features cannot be realized without always-on circuits
- 10x improved response time to event-driven action

Disadvantages

- Quiescent current consumption higher
- Potential degradation in circuit performance due to low I_Q consideration
- Sensor heating is dependent on voltage and not power
  - > Potential degradation in lifetime

Conclusions

Improving system performance requires a holistic approach at a system level

In many cases, the use of small building-block power and supervisory components can simplify the process to achieve a high level of performance

Quiescent current is an important consideration – but knowing the system requirements and making the right tradeoffs to optimize the system performance is the key to success

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Thank You