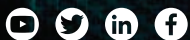




AHEAD OF WHAT'S POSSIBLE™

# ULTRALOW POWER VOLTAGE REGULATOR, SUPERVISORY, AND PMIC

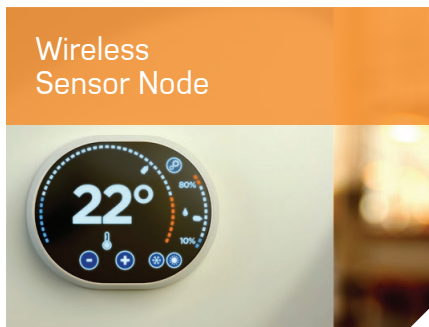
*For Wireless Sensor Nodes, Wearable  
(Health Monitoring Access), and  
Cloud Connected Gateways*



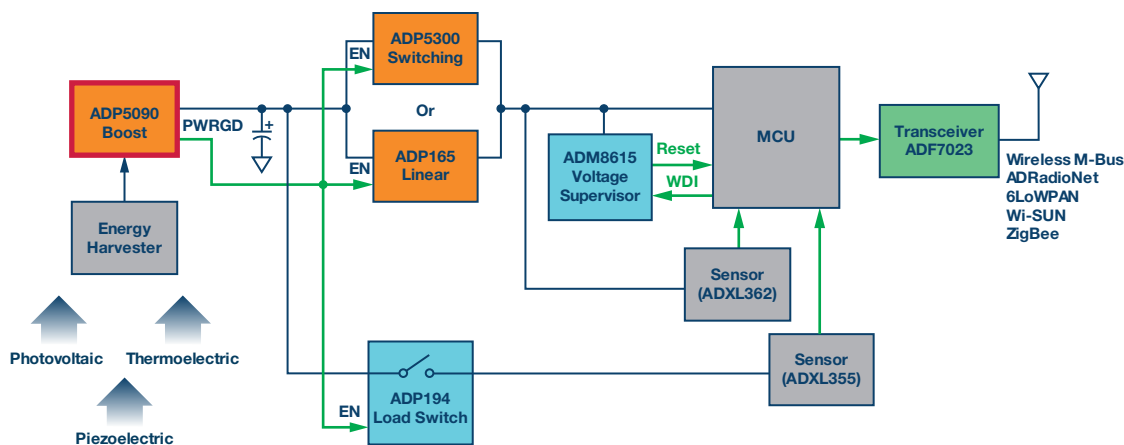
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# Emerging “Internet of Things” Drives ULP Need

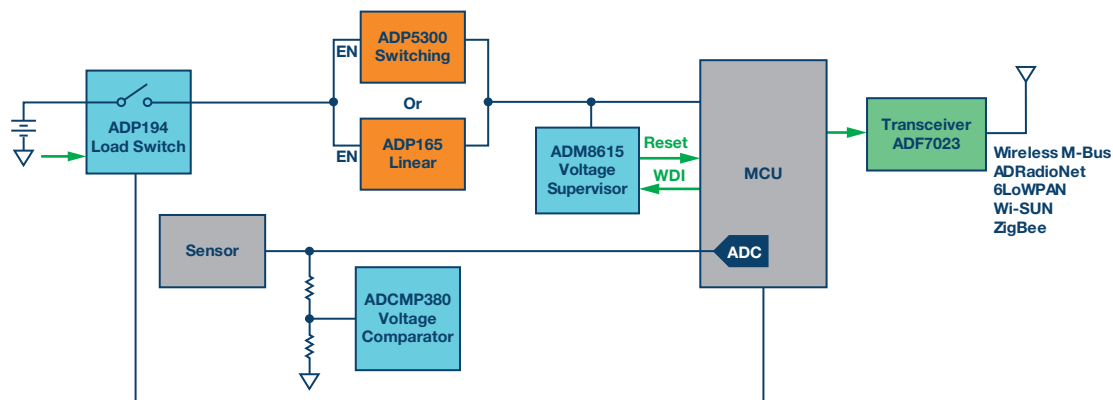


## Internet of Things Powered by Energy Harvesting



- ▶ Energy harvesting
  - ADP5090: ULP boost charger with MPPT
- ▶ Voltage regulation
  - ADP530x: <0.2  $\mu$ A I/Q buck regulator with supervisory
  - ADP165: <0.7  $\mu$ A I/Q linear regulator
- ▶ Leakage current blocking
  - ADP194: <0.7  $\mu$ A IGND load switch
- ▶ Microcontroller reset
  - ADM8615: <0.1  $\mu$ A I/Q voltage supervisor and watchdog timer

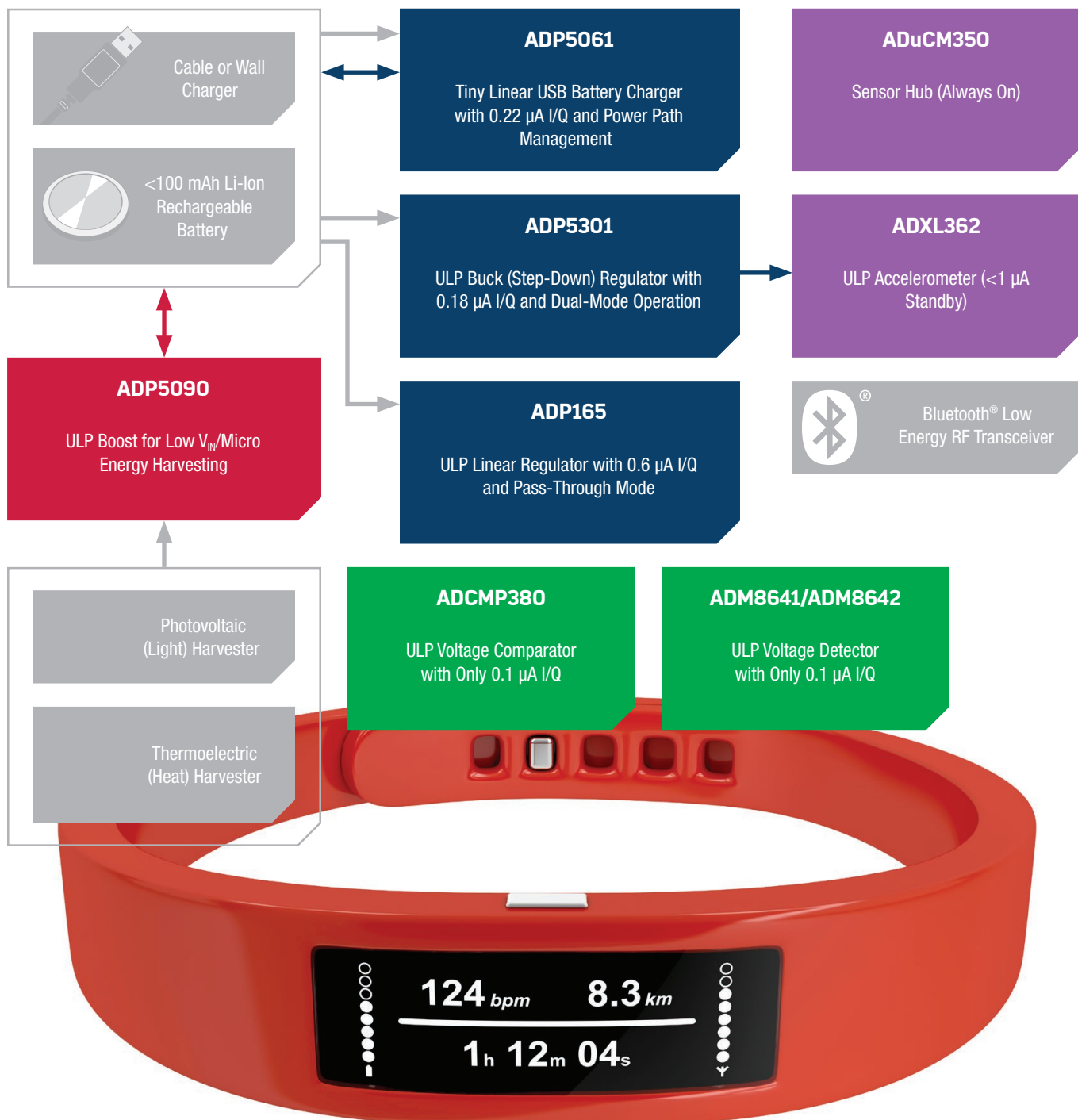
## Internet of Things Powered by Battery



- ▶ Voltage regulation
  - ADP530x: <0.2  $\mu$ A I/Q buck regulator with supervisory
  - ADP165: <0.7  $\mu$ A I/Q linear regulator
- ▶ Microcontroller reset
  - ADM8615: <0.1  $\mu$ A I/Q voltage supervisor and watchdog timer
- ▶ Sensor output detection
  - ADCMP380: <0.1  $\mu$ A I/Q voltage comparator

## Wearable Devices Supported by Ultralow Power System

- ▶ Voltage regulation
  - **ADP5301**: 180 nA I/Q buck regulator with supervisory in 1.6 mm × 1.8 mm
  - **ADP165**: 600 nA I/Q linear regulator
- ▶ Li-Ion battery charger
  - **ADP5061**: 220 nA I/Q USB compliance with power path in 2 mm × 2.5 mm
- ▶ Energy harvesting
  - **ADP5090**: 260 nA I/Q nanopower boost charger
- ▶ Ultralow power supervisory
  - **ADM8641/ADM8642**: 92 nA I/Q voltage detector
  - **ACMP380**: 92 nA I/Q voltage comparator



# Microenergy Harvesting for Photovoltaic and Thermoelectric

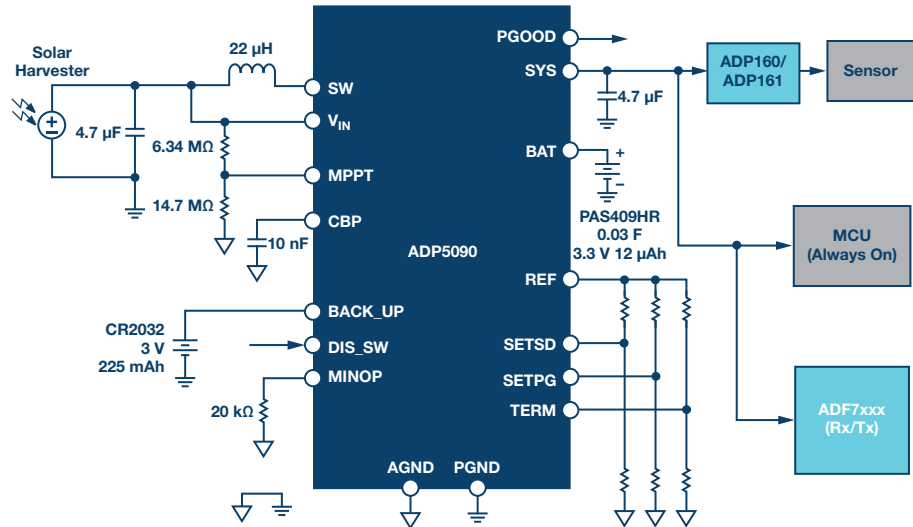
## Ultralow Power Regulator for Microenergy Harvesting

Analog Devices introduces ultralow power boost regulators for photovoltaic and thermoelectric energy harvesting systems. The ADP5090 optimizes efficient conversion of the harvested limited power down to the 15  $\mu\text{W}$  to 1 mW range with best-in-class sub- $\mu\text{W}$  operation losses. Programmable maximum power point tracking with harvester open circuit voltage sensing ensures that the most energy is extracted from the harvester. The 260 nA quiescent current used in deep sleep mode prolongs operation time with minimal loss in the absence of ambient energy. Integrated charge pump circuitry enables a cold start at 380 mV input voltage with no energy on the system node.

In addition to efficient ultralow power conversion, ADP5090 provides the best system design flexibility with support of charging different energy storage through external resistor programmability. An optional backup cell battery can be connected to the ADP5090 that intelligently manages and prioritizes power paths with fully integrated power switches. ADP5090 is capable of stopping a switcher within 10  $\mu\text{s}$  delay to proceed transmitting data via an RF transceiver without interference by switching noise.

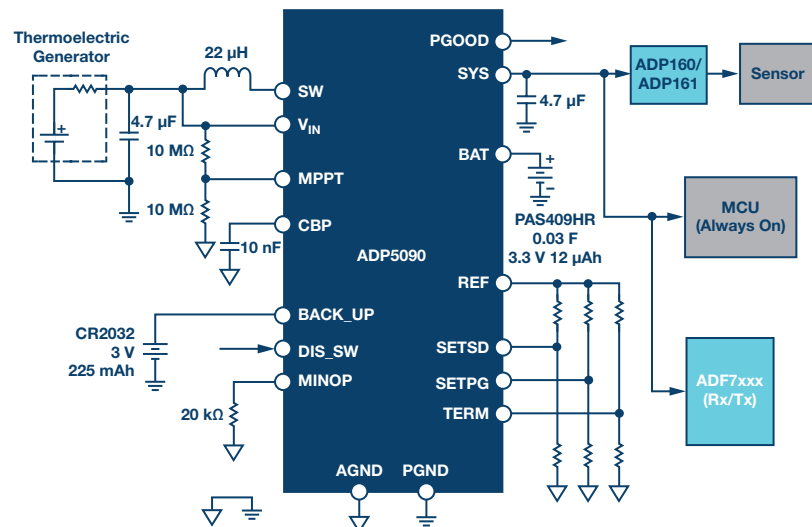
### Photovoltaic Cell/ Solar Panel

- ▶ GaAs thin film: Alta Devices
- ▶ A-Silicon: Sanyo
- ▶ Dye sensitized solar cell: GCell, ElectricFilm



### Thermoelectric Generator

- ▶ Thin film TEG—LairdTech eTEG HV56
- ▶ Buck TEG—Marlow eTEG HV56



## ADP5090 Key Features

### Ultralow Power Boost Regulator

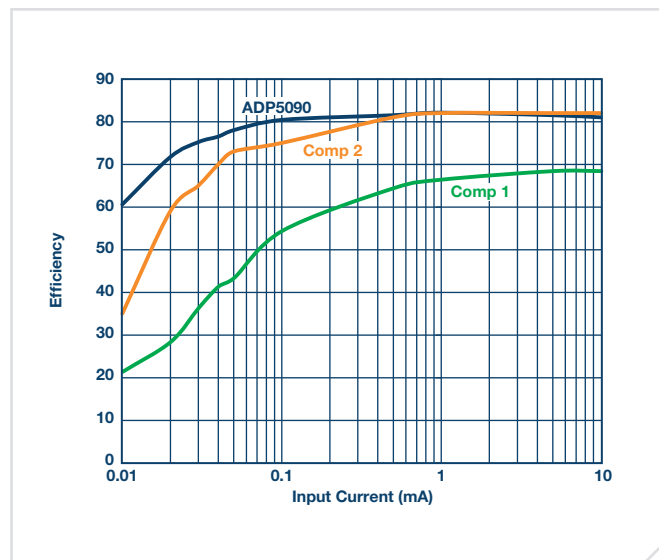
- ▶ Hysteretic controller optimizes sub-1 mW efficiency
- ▶ Cold start from 16  $\mu$ W at  $V_{IN} = 380$  mV
- ▶ Ultralow quiescent current
  - I/Q (sys) = 320 nA when  $V_{IN}$  (OCV) > MINIOF
  - I/Q (sys) = 260 nA when  $V_{IN}$  (OCV) < MINIOF
- ▶ OCV (open circuit voltage) sensing maximum power point tracking
- ▶ Programmable MPPT ratio for PV or TEG
- ▶ Programmable switcher shutdown point (MINOP)

### Energy Storage Management

- ▶ Programmable charging termination voltage and shutdown voltage level to prevent over charging and over discharging
- ▶ Supports optional backup battery power path (primary cell battery)

### RF Transmission Friendly

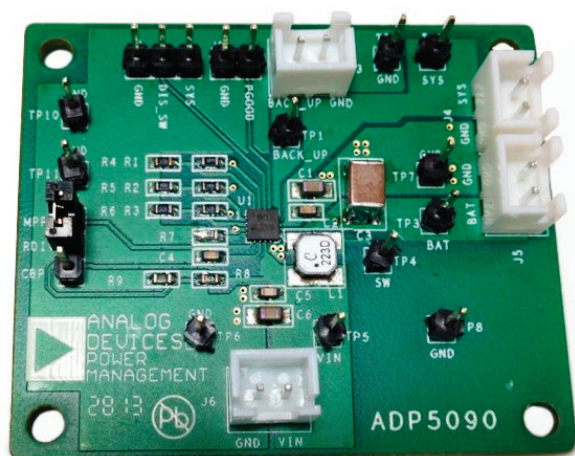
- ▶ Ability to shut down switcher temporarily via MCU communication



Part Number	Topology	Quiescent Current (Standby Current)	$V_{IN}$ Operating Range	$V_{IN}$ Cold Startup (mV)	Max Input Current (mA)	Termination Charging Voltage (V)	Shutdown Discharging Voltage	Accuracy Over Temperature (%)	Cell Type	Package	Price @ 1k (\$U.S.)
ADP5090	Switching/boost	320 nA (CBP > MINOP), 260 nA (CBP < MINOP)	80 mV to 3.3 V	380	100	2.2 to 5.2	2.0 V to $V_{TERM}$	3	SuperCap Li-Ion	3.0 mm $\times$ 3.0 mm, 16-lead LFCSP	1.99

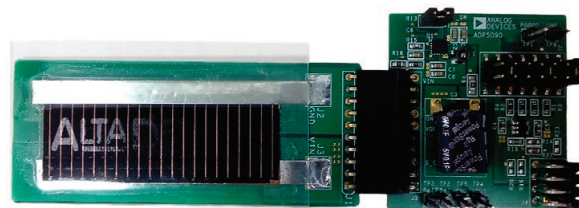
## ADP5090 Evaluation Boards

### ADP5090-1-EVALZ



- ▶ Flexibility to connect to any harvester, any battery, any backup energy storage, and any load with simple 2-lead connectors
- ▶ Test points for detailed product performance evaluation

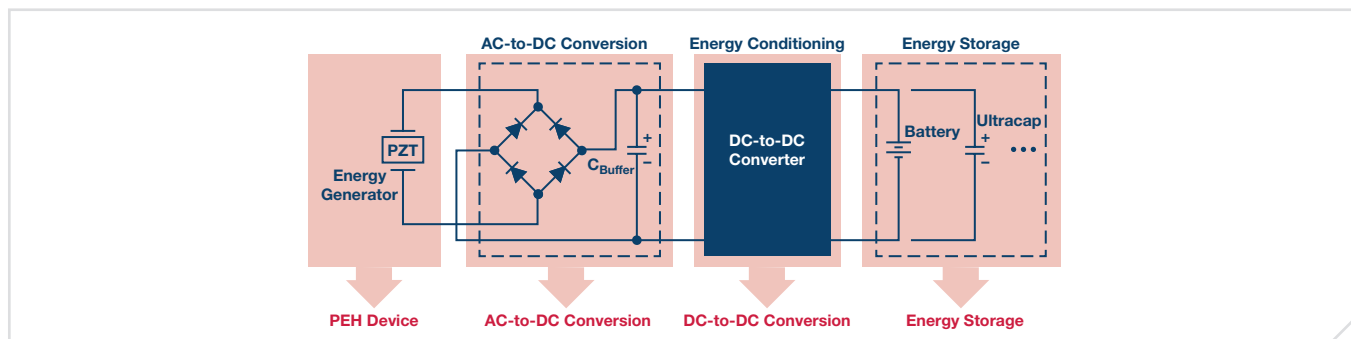
### ADP5090-2-EVALZ



- ▶ Plug and play with PV panel
- ▶ Easy connection to other harvesters
- ▶ Large pads allow different energy storage options
- ▶ Jumpers allow for different load voltage
- ▶ Backup CR2032 coin cell battery on back of board

# Microenergy Harvesting for Piezoelectric

## Diagram of Piezoelectric Energy Harvesting System



## ADP5304 as Piezo Harvester PMU

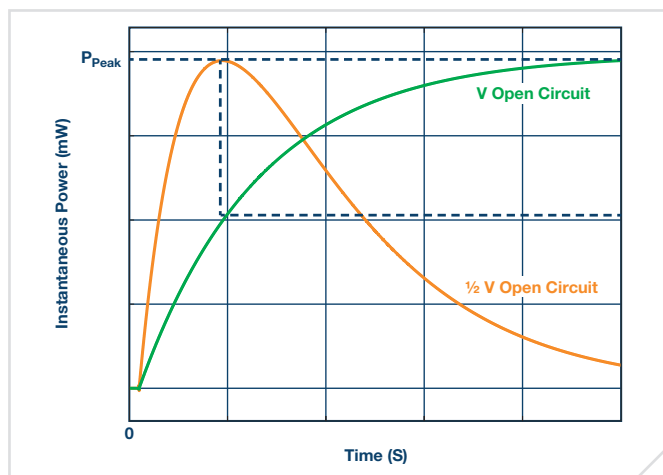
**VINOK hysteresis window control ADP5302 buck switching timing as MPPT control at programmable PEZ**

- Handles high output impedance from piezoelectric harvester—ADP5304 programmable VINOK with hysteresis window as MPPT scheme to enable/disable DIS\_SW
- Optimizes pass through mode ( $V_{IN} = V_{OUT}$ )—ADP5304 to support 100% duty cycle

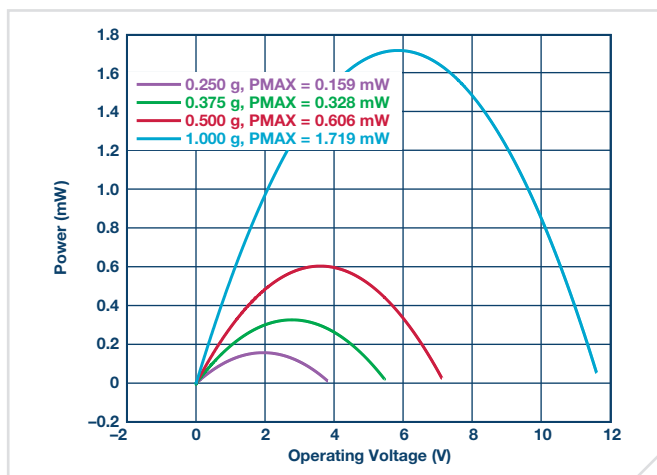
### Programmable VINOK Monitor Threshold as a Piezoelectric Harvester MPPT Point

Option	Description
Option 0	VINOK monitor threshold = 2.05 V
Option 1	VINOK monitor threshold = 2.10 V
Option 2	VINOK monitor threshold = 2.15 V
Option 3	VINOK monitor threshold = 2.20 V
...	
Option 20	VINOK monitor threshold = 3.00 V (default)
...	
Option 62	VINOK monitor threshold = 5.10 V
Option 63	VINOK monitor threshold = 5.15 V

## Typical Power and Voltage vs. Time



## Tuned to 180 Hz, 0 Gram Tip Mass



Part Number	Topology	Configuration	Quiescent Current with No Load	$V_{IN}$ Operating Range (V)	$V_{OUT}$ Programmable Range	Max Output Current (mA)	VOUTOK (Power Good)	VINOK (Low Battery Warning)	Special Features	Package	Price @ 1k (U.S.)
ADP5304	Switching	1 × buck	180 nA ( $V_{IN} = 4.2 V$ )	2.05 to 6.5	Adjustable via single resistor with 32 level	500	N/A	N/A	Input power impedance match to support piezoharvesting power conversion	10-lead LFCSP	0.95

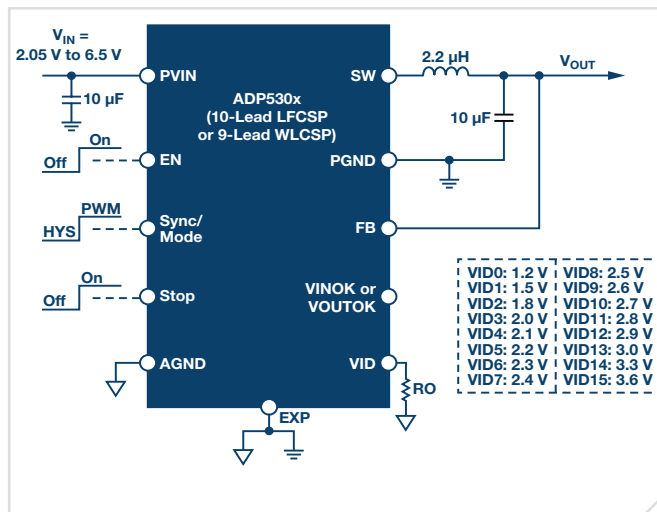
# Ultralow Power Switching Regulator

## ADP5300/ADP5301/ADP5302/ADP5303: Ultralow Power Buck

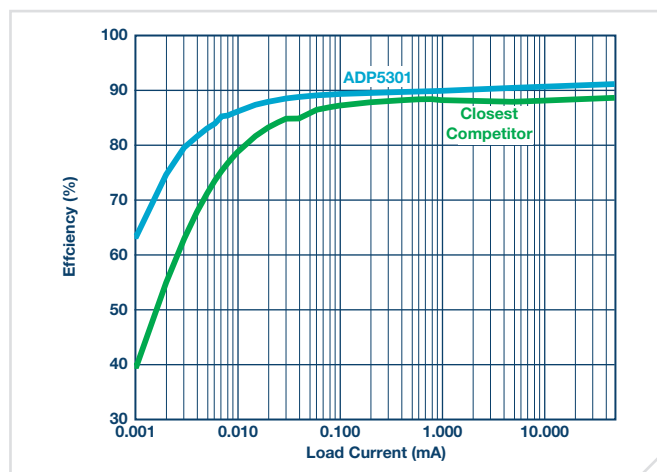
Hysteretic/PWM mode controls for always alive rail and ultralow power microconverter/RF/sensor with voltage supervisory.

### Features

- ▶ Ultralow power step-down regulator
  - 180 nA quiescent current in regulation with zero load
  - Excellent efficiency in sub-1 mW operation range
  - Adjustable/fixed output options via factory fuse
- ▶ Low output noise with fixed switching frequency
  - Selectable operation mode (FPWM or hysteretic)
  - Output current up to 500 mA under FPWM mode
  - 600 kHz or 1.2 MHz switching frequency and optional synchronization input from 400 kHz to 1.4 MHz
  - ±1.5% output voltage regulation accuracy
  - 100% duty cycle operation mode
- ▶ Flexible voltage supervisory
  - Monitor  $V_{OUT}$  as PGOOD flag: [ADP5300/ADP5301](#)
  - Monitor  $V_{IN}$  as LOW\_BAT indicator: [ADP5302/ADP5303](#)
  - Stop switching pin: ADP5300/ADP5302



ADP530x functional block diagram.

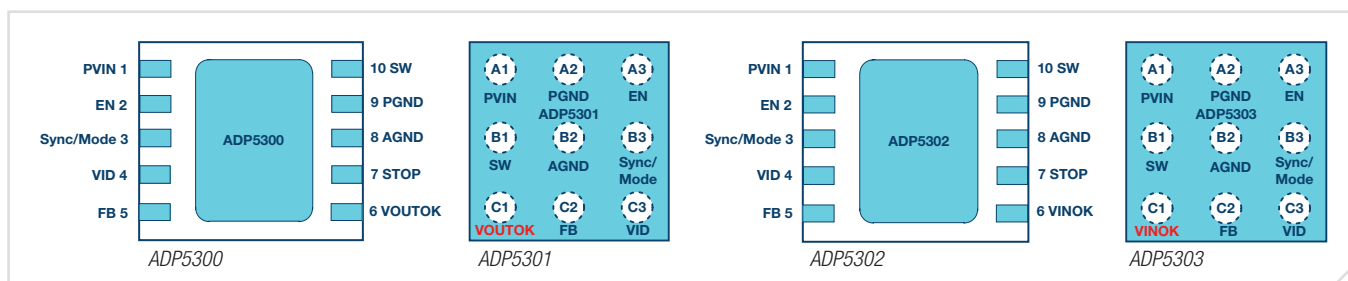


ADP5300 superior efficiency in ultralight load with a step-down range of 4.2 V to 1.8 V.

Input Voltage	Min: 2.05 V Max: 6.50 V
Efficiency @ $V_{in} = 4.2 V$	82% at 10 $\mu A$ @ 1.8 V, 90% at 15 mA @ 1.8 V, 90% at 400 mA @ 1.8 V
Programmability	Resistor adjustable or factory trimming
Package Options	10-lead LFCSP (3 mm × 3 mm), 9-lead WLCSP (1.65 mm × 1.87 mm)
Applications	Always alive power rail in portable device batteries/energy harvester powered devices

## Flexible Voltage Monitoring Features

Part Number	Topology	Configuration	Quiescent Current with No Load	$V_{in}$ Operating Range (V)	$V_{out}$ Programmable Range	Max Output Current (mA)	VOUTOK (Power Good)	VINOK (Low Battery Warning)	Special Features	Package	Price @ 1k (\$U.S.)
<a href="#">ADP5300</a>	Switching	1 × buck	180 nA ( $V_{in} = 4.2 V$ )	2.05 to 6.5	Adjustable via single resistor with 32 level	500	Yes	N/A	Selectable hysteretic or FPWM mode, optional sync clocking, quick output discharge option	10-lead LFCSP	0.95
<a href="#">ADP5301</a>	Switching	1 × buck	180 nA ( $V_{in} = 4.2 V$ )	2.05 to 6.5	Adjustable via single resistor with 32 level	500	Yes	N/A	Selectable hysteretic or FPWM mode, optional sync clocking, quick output discharge option	9-ball WLCSP	0.95
<a href="#">ADP5302</a>	Switching	1 × buck	280 nA ( $V_{in} = 4.2 V$ )	2.05 to 6.5	Adjustable via single resistor with 32 level	500	N/A	Yes	Selectable hysteretic or FPWM mode, optional sync clocking, quick output discharge option	10-lead LFCSP	0.95
<a href="#">ADP5303</a>	Switching	1 × buck	280 nA ( $V_{in} = 4.2 V$ )	2.05 to 6.5	Adjustable via single resistor with 32 level	500	N/A	Yes	Selectable hysteretic or FPWM mode, optional sync clocking, quick output discharge option	9-ball WLCSP	0.95



# Ultralow Power Linear Regulator

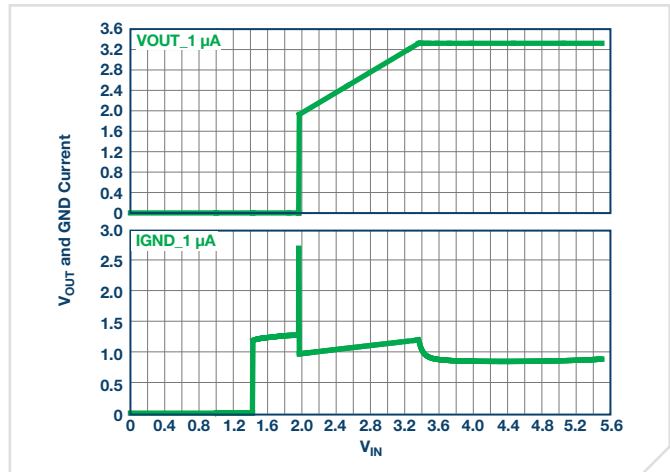
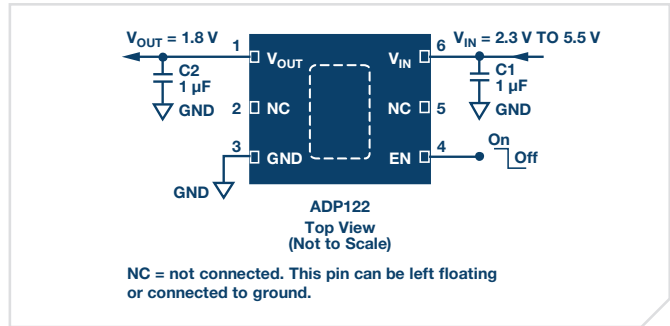
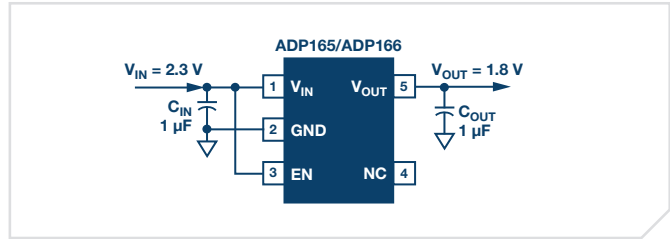
## ADP165/ADP166 Very Low Quiescent Current 150 mA LDO with Pass Through Mode

### Features

- ▶ Very low quiescent current
  - I/Q = 560 nA with 0  $\mu$ A load
  - I/Q = 860 nA with 1  $\mu$ A load
- ▶ Maintains very low quiescent current in dropout (pass through mode):
  - I/Q\_DROP = 780 nA with 0  $\mu$ A load
  - I/Q\_DROP = 1200 nA with 1  $\mu$ A load
- ▶ Stable with 1  $\mu$ F  $\pm$  30% ceramic input and output capacitors
- ▶ Maximum load current (ILOAD\_MAX): 150 mA
- ▶ Input voltage range: 2.2 V to 5.5 V
- ▶ Low shutdown current: 50 nA typical
- ▶ Low dropout voltage: 120 mV at 150 mA load
- ▶ Initial output voltage accuracy:  $\pm$ 1%
- ▶ Accuracy over line, load, and temperature:  $\pm$ 3.5%
- ▶ Seven fixed output voltage options: 1.2 V to 3.3 V
- ▶ Adjustable output option can be set from 1.2 V to 4.2 V
- ▶ PSRR performance of 72 dB at 100 Hz, V<sub>OUT</sub> = 1.2 V
- ▶ Current-limit and thermal overload protection
- ▶ Logic control enable
- ▶ Integrated output discharge resistor—ADP165 only
- ▶ Three package options
  - 5-lead TSOT package
  - 6-lead, 2 mm  $\times$  2 mm LFCSP
  - 4-ball, 0.5 mm pitch WLCSP

### Applications—Always On Power for RTC and Sequencers

- ▶ Portable and battery operated equipment
- ▶ Wireless system network
- ▶ Metering
- ▶ Weigh scales



Part Number	V <sub>IN</sub> Range (V)	V <sub>OUT</sub> Options or Adj Range (V)	I <sub>OUT</sub> (mA)	Supply Current No Load Typical ( $\mu$ A)	Supply Current Full Load Typical ( $\mu$ A)	Quick Output Discharge	Pass-Through Mode	RMS Noise @ 10 Hz to 100 kHz	PSRR @ 1 MHz (dB) ( $\mu$ V rms)	Package
ADP160	2.2 to 5.5	Fixed: 1.2 to 4.2	150	0.56	42	Yes	No	80	25	5-lead TSOT, 1 mm $\times$ 1 mm, 4-ball WLCSP
ADP161	2.2 to 5.5	Adjustable: 1.2 to 4.2	150	0.56	42	Yes	No	80	25	5-lead TSOT
ADP162	2.2 to 5.5	Fixed: 1.2 to 4.2	150	0.56	42	No	No	80	25	5-lead TSOT, 1 mm $\times$ 1 mm, 4-ball WLCSP
ADP163	2.2 to 5.5	Adjustable: 1.2 to 4.2	150	0.56	42	No	No	80	25	5-lead TSOT
ADP165 <i>New</i>	2.2 to 5.5	Fixed: 1.2 to 4.2, adjustable: 1.0 to 4.2	150	0.59	42	Yes	Yes	80	25	5-lead TSOT, 2 mm $\times$ 2 mm, 6-lead LFCSP, 1 mm $\times$ 1 mm, 4-ball WLCSP
ADP166 <i>New</i>	2.2 to 5.5	Fixed: 1.2 to 4.2, adjustable: 1.0 to 4.2	150	0.59	42	No	Yes	80	25	5-lead TSOT, 2 mm $\times$ 2 mm, 6-lead LFCSP, 1 mm $\times$ 1 mm, 4-ball WLCSP

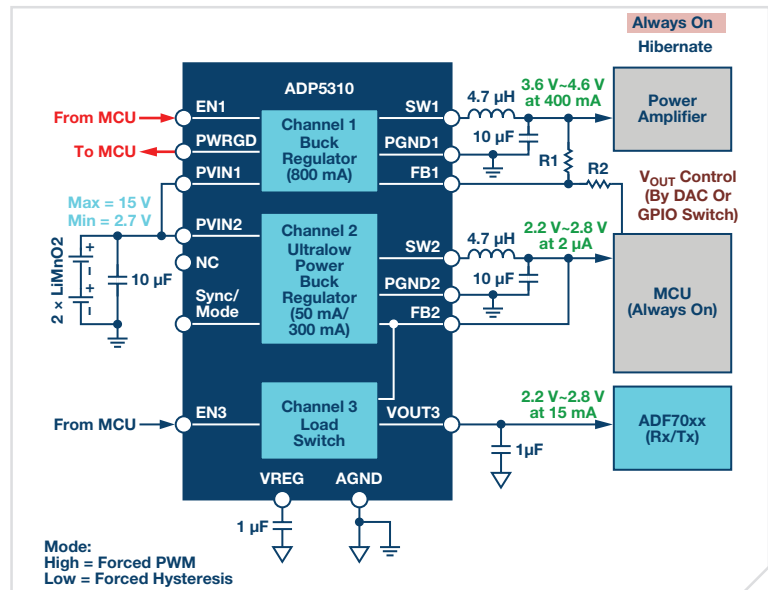


# Ultralow Power PMIC

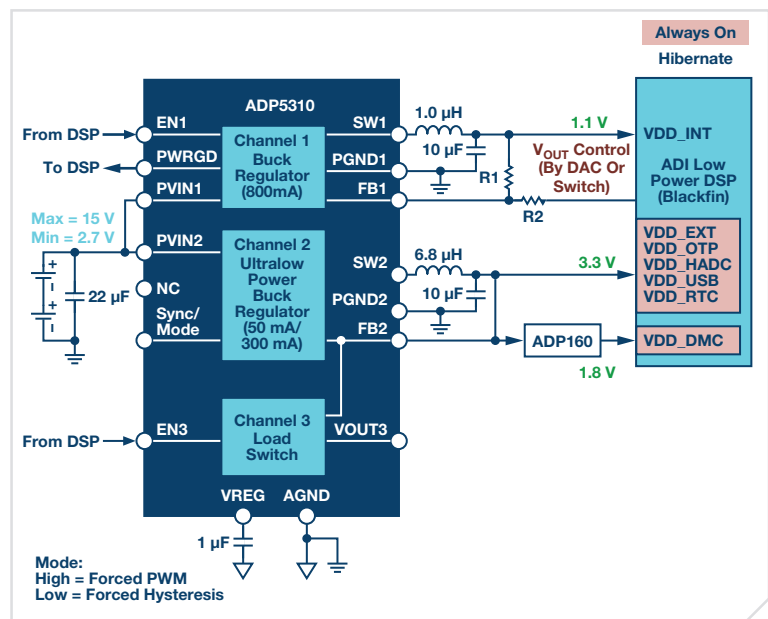
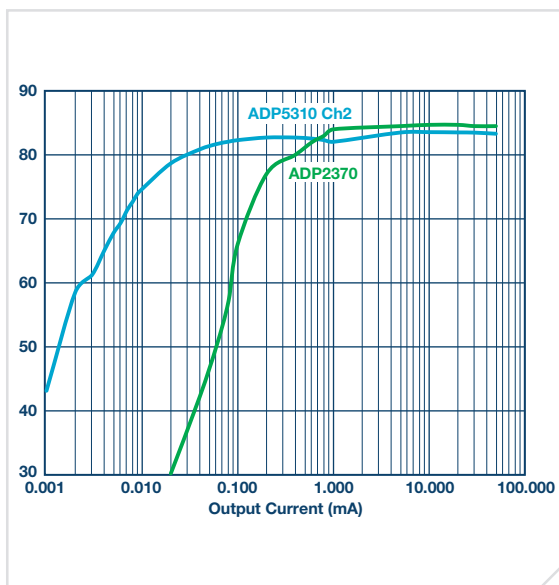
## Ultralow Power DC-to-DC Regulator

Analog Devices introduces a new ultralow power regulator, the **ADP5310**, which consumes extremely little current during voltage regulation. It generates superior efficiency, particularly in ultralight load condition such as sub-1 mW compared with other dc-to-dc switches. For battery-powered applications where systems need to be always on but consuming current as low as ten microamps. Unlike traditional PSM (power saving mode), which still consumes tens of microamp quiescent current, ADP5310 has only 600 nA I/Q, which enables the efficient conversion of up to a tens of microamps load.

Moreover, the ADP5310 is equipped with a selectable forced PWM mode that allows for low noise output voltage when powering an analog sensitive load. ADP5310 benefits battery-powered systems with an extended battery life and offers high efficiency in standby mode and active mode. The ADP5310 also mitigates noise interference with analog loads.



ULP micro-PMU for smart metering RF module.




ULP micro-PMU for low power DSP companion.

Part Number	Topology	Configuration	Quiescent Current (CH2 in regulation; CH1 = CH3 = Off)	V <sub>IN</sub> Operating Range	V <sub>OUT</sub> Programmable Range	Max Output Current	Special Features	Package	Price @ 1k (\$U.S.)
ADP5310	Switching (buck)	2 × buck 1 × load switch	620 nA (V <sub>IN</sub> = 6.0 V)	2.7 V to 15.0 V	CH1: 1.2 V, 1.5 V, 1.8 V, 2.5 V, 2.85 V, 3.3 V, 5 V or adjustable CH2: 1.2 V to 5.0 V (50 mV per step) or adjustable	CH1: 800 mA CH2: 300 mA	Selectable hysteretic or FPWM mode, optional sync clocking, quick output discharge option	16-lead TSSOP-EP	1.99

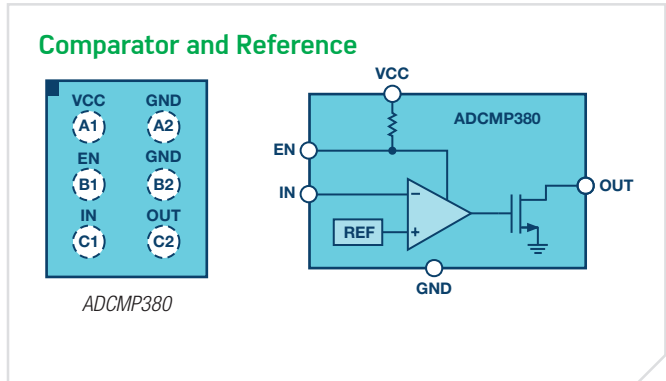
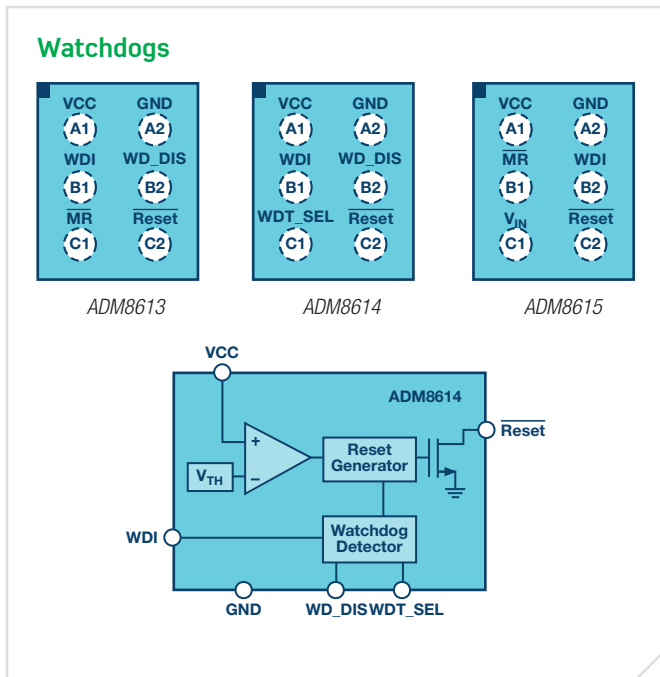
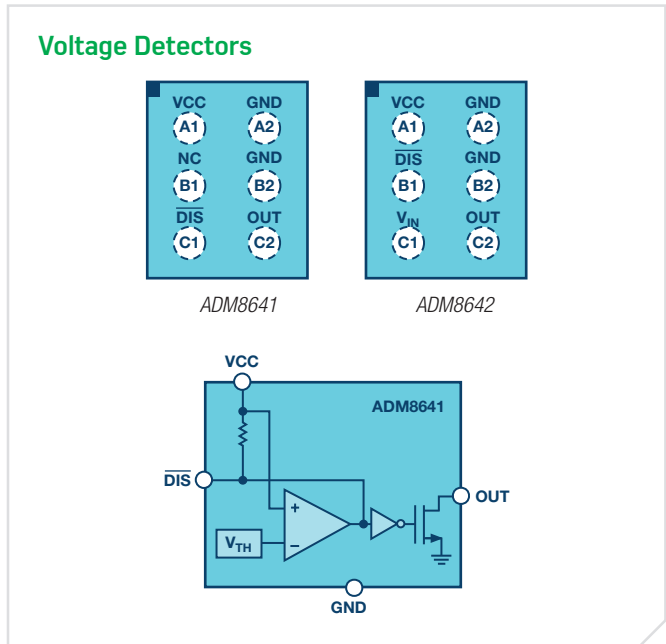
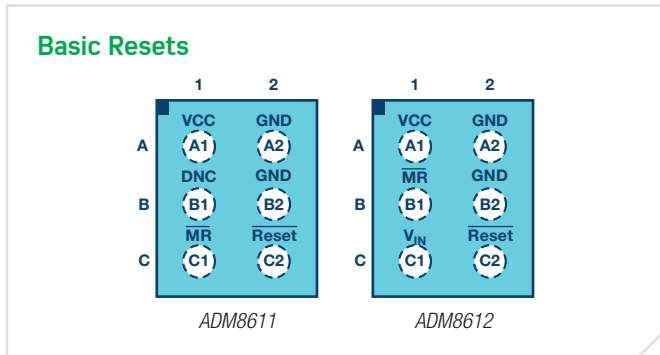
# Ultralow Power Supervisory: Reset and Watchdog Timer

## Ultralow Power Supervisory

- ▶ Lowest power consumption in the industry
- ▶ <125 nA power consumption over temperature
- ▶ Precision monitoring
- ▶ ±1.5% threshold accuracy
- ▶ Supervisor, comparator, and reference
- ▶ Based on switched capacitor architecture for the reference and divider
- ▶ Real-time response (not a sampled architecture)

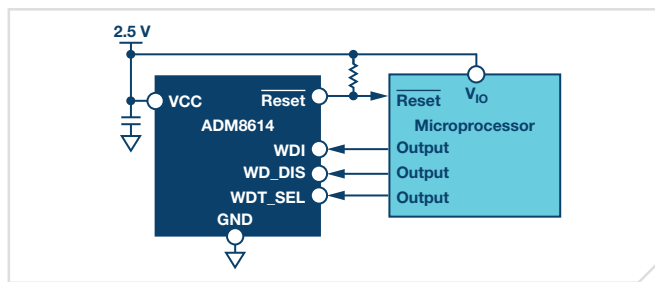
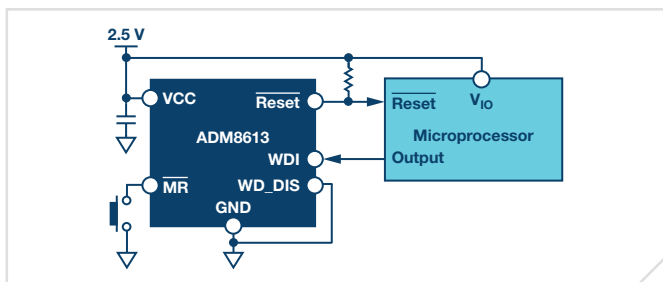
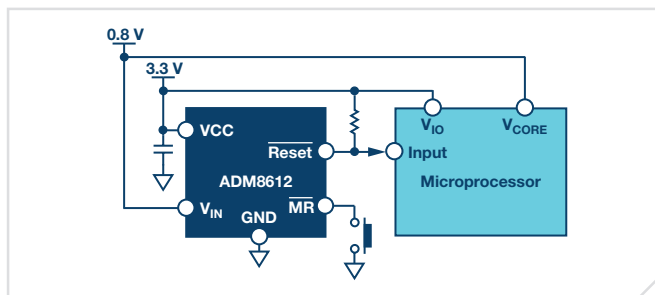
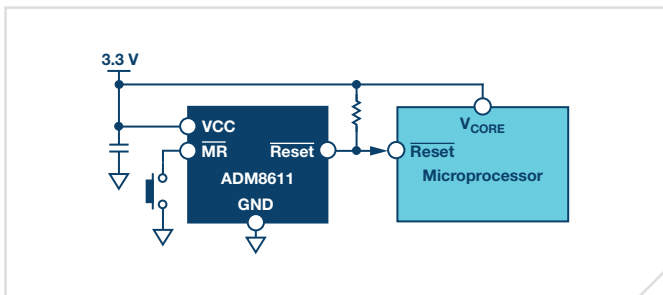
125 nA Max Supply Current	
Reset Thresholds from 1.8 V to 4.63 V	
Watchdog Timers	
WLCSP Packaging	

## Ultralow Power Monitoring Portfolio



## ADM861x Selection Table

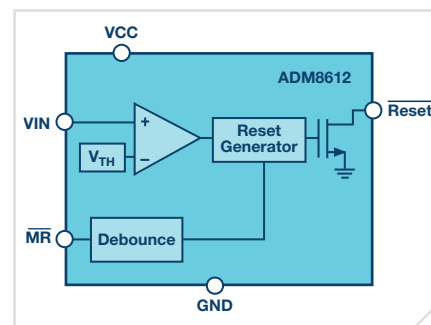
Part Number	Low Voltage Monitoring	Manual Reset	Watchdog Timer	Watchdog Disable Input	Watchdog Timeout Selection Input
ADM8611	—	Yes	—	—	—
ADM8612	Yes	Yes	—	—	—
ADM8613	—	Yes	Yes	Yes	—
ADM8614	—	—	—	Yes	Yes
ADM8615	Yes	Yes	Yes	—	—



## ADM8611/ADM8612 Ultralow Power Microprocessor Supervisory with Manual Reset

### Features

- ▶ Ultralow power consumption  $I_{CC} = 92$  nA (typ)
- ▶ Continuous monitoring with no blank time
- ▶ Precision, low voltage monitoring down to 0.5 V
- ▶ Pretrimmed monitoring threshold options
  - 10 options from 2 V to 4.63 V for [ADM8611](#)
  - 20 options from 0.5 V to 1.9 V for [ADM8612](#)
- ▶  $\pm 1.3\%$  threshold accuracy over full temperature range
- ▶ Manual reset input
- ▶ 200 ms (typical) reset timeout
- ▶ Low voltage input monitoring down to 0.5 V (ADM8612)
- ▶ Active low, open-drain reset output
- ▶ Power supply glitch immunity
- ▶ Available in 1.46 mm  $\times$  0.96 mm WLCSP
- ▶ Operational temperature range:  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$

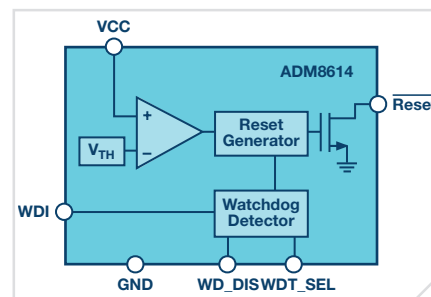


Part Number	Reset Threshold (V)	Min Reset Timeout (ms)	Reset Output Stage	Manual Reset Capability	Supply Current Typ ( $\mu\text{A}$ )	Typ Watchdog Timeout (ms)	Package	Price @ 1k (\$U.S.)
<a href="#">ADM8611</a>	2 to 4.63	140	Open-drain	Yes	0.092	—	1.5 mm $\times$ 1 mm, 6-ball WLCSP	0.39
<a href="#">ADM8612</a>	0.6 to 1.9	140	Open-drain	Yes	0.092	—	1.5 mm $\times$ 1 mm, 6-ball WLCSP	0.42

## ADM8613/ADM8614/ADM8615 Ultralow Power Microprocessor Supervisory with Watchdog Timer

### Features

- ▶ Ultralow power consumption with  $I_{CC} = 92$  nA (typ)
- ▶ Continuous monitoring with no blank time
- ▶ Precision, low voltage monitoring down to 0.5 V
- ▶ Pretrimmed monitoring threshold options
  - 20 options from 0.5 V to 1.9 V for [ADM8615](#)
  - 5 options from 2.32 V to 4.63 V for [ADM8613/ADM8614](#)
- ▶  $\pm 1.3\%$  threshold accuracy over full temperature range
- ▶ Manual reset input
- ▶ 200 ms (typical) reset timeout
- ▶ Low voltage input monitoring down to 0.5 V
- ▶ Available in 1.46 mm  $\times$  0.96 mm WLCSP
- ▶ Operational temperature range:  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$
- ▶ Watchdog timer
- ▶ Watchdog function disable input
- ▶ Watchdog timeout extension input
- ▶ Active low, open-drain RESET output
- ▶ Power supply glitch immunity



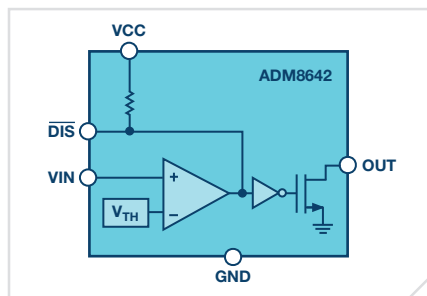
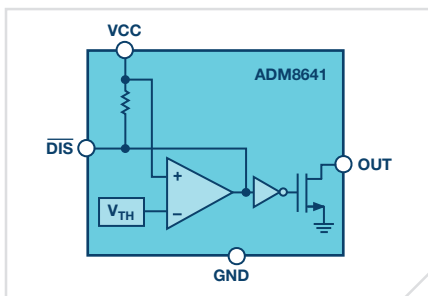
Part Number	Reset Threshold (V)	Min Reset Timeout (ms)	Reset Output Stage	Supply Current Typ ( $\mu\text{A}$ )	Typ Watchdog Timeout (ms)	Package	Price @ 1k (\$U.S.)
<a href="#">ADM8613</a>	2.32 to 4.63	140	Open-drain	0.092	1600/25,600	1.5 mm $\times$ 1 mm, 6-ball WLCSP	0.59
<a href="#">ADM8614</a>	2.32 to 4.63	140	Open-drain	0.092	1600/100,000	1.5 mm $\times$ 1 mm, 6-ball WLCSP	0.59
<a href="#">ADM8615</a>	0.5 to 1.9	140	Open-drain	0.092	1600/25,600	1.5 mm $\times$ 1 mm, 6-ball WLCSP	0.59

# Ultralow Power Supervisory: Voltage Detector and Comparator

## ADM8641/ADM8642 Ultralow Power Voltage Detector

### Features

- ▶ Ultralow power consumption with  $I_{CC} = 92 \text{ nA}$  (typical)
- ▶ Precision low voltage monitoring
- ▶ Pretrimmed monitoring threshold options
- ▶ 10 options from 2 V to 4.63 V for the ADM8641
  - 20 options from 0.5 V to 1.9 V for the ADM8642
  - $\pm 1.2\%$  threshold accuracy over full temperature range
- ▶ Output disable input
- ▶ 23  $\mu\text{s}$  to 26  $\mu\text{s}$  typical propagation delay
- ▶ Open-drain type output
- ▶ Power supply glitch immunity
- ▶ Available in a 1.46 mm  $\times$  0.96 mm WLCSP
- ▶ Operational temperature range:  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$

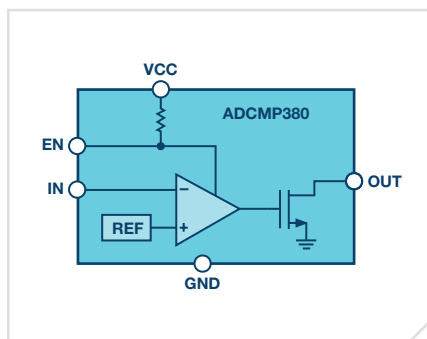


Part Number	Reset Threshold (V)	Min Reset Timeout (ms)	Reset Output Stage	Manual Reset Capability	Supply Current Typ ( $\mu\text{A}$ )	Package	Price @ 1k (U.S.)
ADM8641	2 to 4.63	0	Open-drain	Yes	0.092	1.5 mm $\times$ 1 mm, 16-lead WLCSP	0.25
ADM8642	0.6 to 1.9	0	Open-drain	Yes	0.092	1.5 mm $\times$ 1 mm, 16-lead WLCSP	0.25

## ADCMP380 Ultralow Power Voltage Comparator with Reference

### Features

- ▶ Comparator with on-chip reference
- ▶ Ultralow power consumption with  $I_{CC} = 92 \text{ nA}$  (typical)
- ▶ Precision low voltage monitoring to 0.5 V
- ▶ Accurate internal reference level over full temperature range
  - $\pm 1.6\%$  at 1 V
  - $\pm 2.2\%$  at 0.5 V
- ▶ Enable input
- ▶ 23  $\mu\text{s}$  typical propagation delay
- ▶ Open-drain type output
- ▶ Input glitch immunity
- ▶ Available in a 1.46 mm  $\times$  0.96 mm WLCSP
- ▶ Operational temperature range:  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$



Part Number	Internal Reference	Reference Accuracy (%)	Supply Voltage (V)	Supply Current Typ ( $\mu\text{A}$ )	Input Range (V)	Propagation Delay Typ ( $\mu\text{s}$ )	Hysteresis	Logic I/O	Package	Price @ 1k (U.S.)
ADCMP380	Yes	1.60	2.0 to 5.5	0.092	0 to 5.5	23	Internal	Open-drain	1.46 mm $\times$ 0.96 mm, 16-lead WLCSP	0.39

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