



ADVANCED
LINEAR
DEVICES, INC.

**Depletion Mode MOSFET
Technology Enables
Zero Power™
Energy Backup Systems**



www.aldinc.com

Industry Drives toward 1-Volt or less Systems Ultra Low Power and Secondary Power

- Secondary power sources and energy harvesting
- Eliminate the need to replace power sources
- Remotely operated sensor arrays
- Optimizing battery power
- Trends to reduce power dissipation
- Longer battery life for embedded systems

“System designers in every product category are relentlessly searching for new ways to optimize operating voltage and reduce power consumption. Standing in their way are the limitations inherent in today’s state-of-the-art semiconductor devices”

- Mary Olsson, Semiconductor Analyst, Gartner Inc.



ALD's present Family of EPAD[®] Discretetes

- Zero Threshold MOSFET
- Nano Power EPAD MOSFET– Achieves industry's lowest operating power measured in nanowatts
- Technology sets new level of accuracy in gate threshold and sub-threshold voltages
- Custom threshold voltage combinations for innovative low-power system design





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New EPAD Depletion Mode MOSFETs

Device Characteristics

- Precision Negative Threshold Voltages
- Tight Offset Voltage Matching and Control
- Controlled Sub-threshold Characteristics
- Operating At Below Threshold Voltage (NanoAmp)
- Enables Zero Power Normally-Off Circuits
- Normally-On State Without Applied Power





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Why Depletion Mode MOSFET?

Today's Low Power Design Challenges

- Industry Drive towards secondary power sources
- Smaller batteries and longer operating life
- Alternative and Energy Harvesting Circuits
- Hybrid power circuits (dual power sources)
- Enables entire class of special depletion mode circuits
- Enables new innovation in extremely low-power circuits
- Zero-Power battery backup circuits





ALD EPAD[®] Technology

- Patented and Trademarked
- Precision on-chip trimming and calibration technology
- Incorporates Floating-gate MOSFET transistors
- Precision and ultra low operating voltages
- Proven EPAD[®] manufacturing technology
- 20 Year evolution in technology and manufacturing
- Millions of EPAD[®] enabled circuits shipped to date





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Special Depletion Mode MOSFET Circuits

- Current sources
- Current sinks
- Current limiters
- Variable resistors with control
- Attenuators
- Small signal synchronous rectifiers
- Form C relay functional replacements
- High impedance source followers
- Zero power voltage detectors



Market Applications

- **Electronic Systems and Devices requiring**
 - Micro/Nano power (nW) analog circuit designs
 - Zero Power Backup System
 - Fail Safe Circuits
 - Emergency Backup Systems
 - Electromechanical Relay Replacement
 - Hybrid power (dual power source) modules
 - Energy harvesting circuits





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Energy Harvesting

Accumulate and capture energy when available, condition and save the energy for later use

- **Electronic systems and devices requiring:**
 - Alternative power sources
 - Energy harvesting circuits
 - Piezoelectric & solar energy capture
 - Hybrid power (dual power source) modules
 - Zero standby power (nW)



End-User Applications and Benefits

- Cell Phones – longer battery life supporting more user applications
- Remote sensor arrays – operation powered by alternative energy sources
- Portable medical devices – prolongs useful life, reduces need/frequency for battery replacement
- Automotive and aerospace circuit applications
- Dual energy source portable terminals
- Thousands of industrial applications



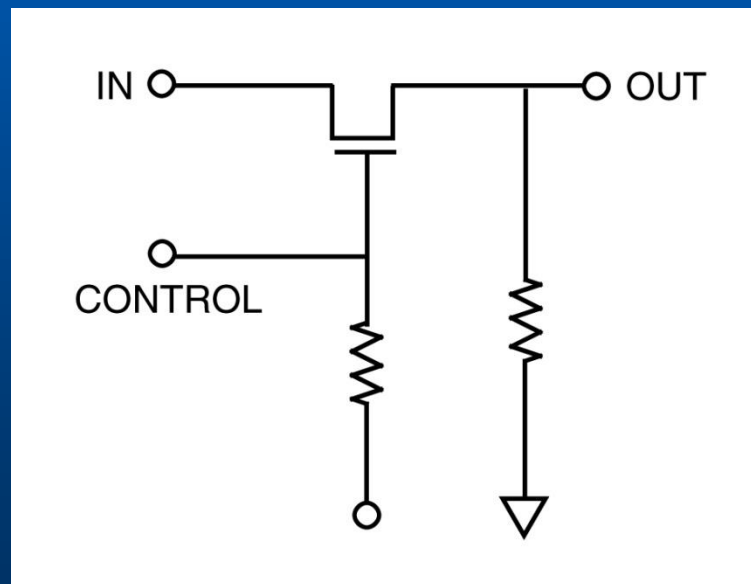
RF Circuits:

- Low **t**hreshold **v**oltage improves **c**ircuit to **a**chieve **n**ew **l**evels of:
 - Precision
 - Signal **s**ensitivity
 - Signal **s**electivity
 - Ultra low voltage
 - NanoPower (nW)

Example: Normally-On Circuit to replace NC Relays

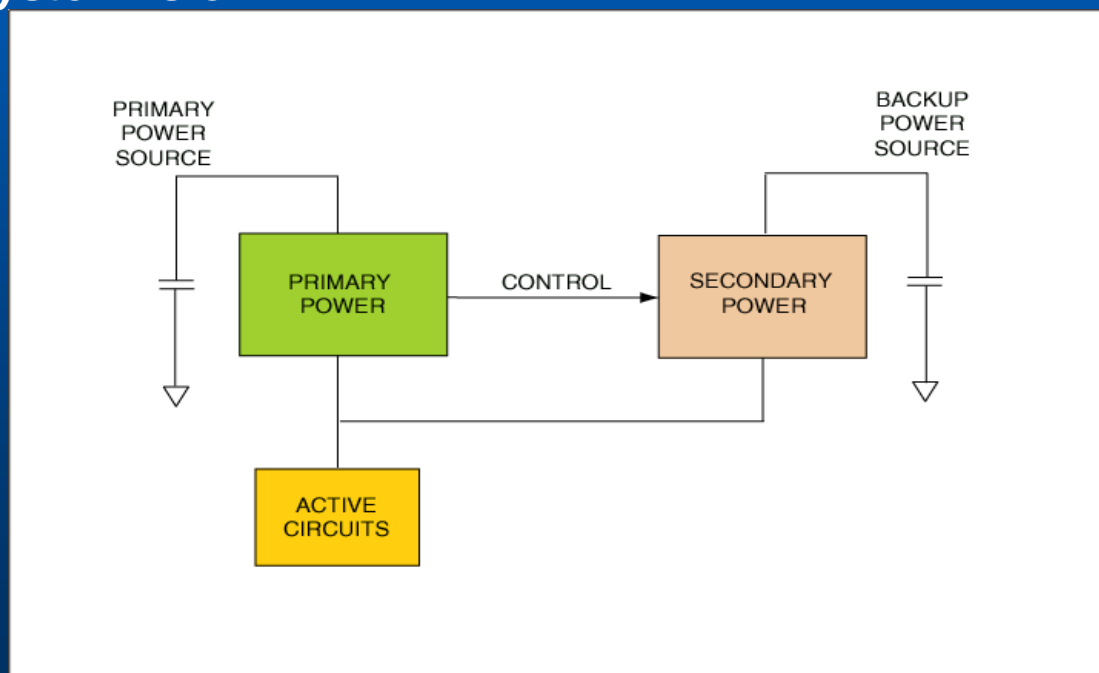
When Control input signal or system power is lost,

the MOSFET turns on: $V_{out} = V_{in}$



Example: Secondary Backup Power Systems

Secondary backup power experience zero power drain when primary power system is on





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Crystal Oscillator

- 1MHz to 16MHz
- Micropower 7 μ A@4MHz
- Low Voltages 0.3V to 0.5V instead of 3V to 5V
- 100x to 1000x power savings





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LC Oscillator

- Micropower 1 to 2 μW
- Low Voltages 0.17V to 0.3V
- Tuned **c**ircuits
- 10KHz to 10MHz





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RC Oscillator

- Nanopower 1.2 nW
- Low voltage 0.14V
- Low frequency 10Hz to 1KHz





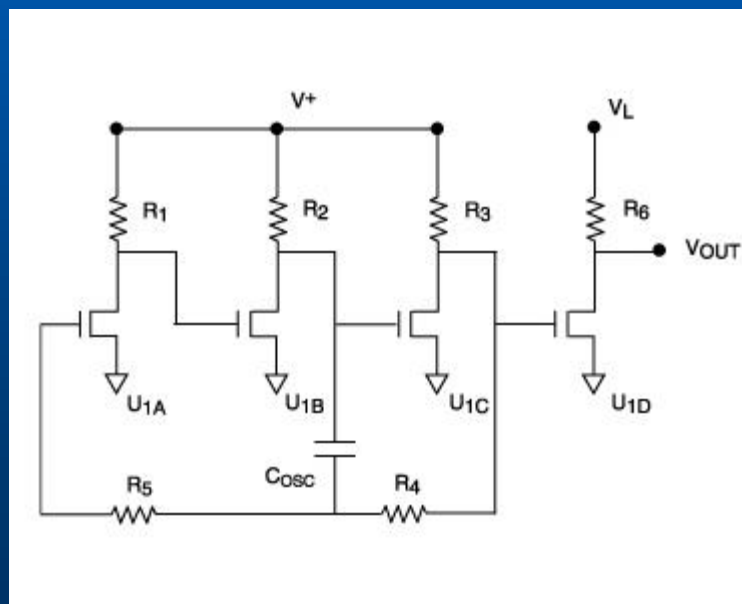
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MOSFET Transistors

Example: Nanowatt RC Oscillator

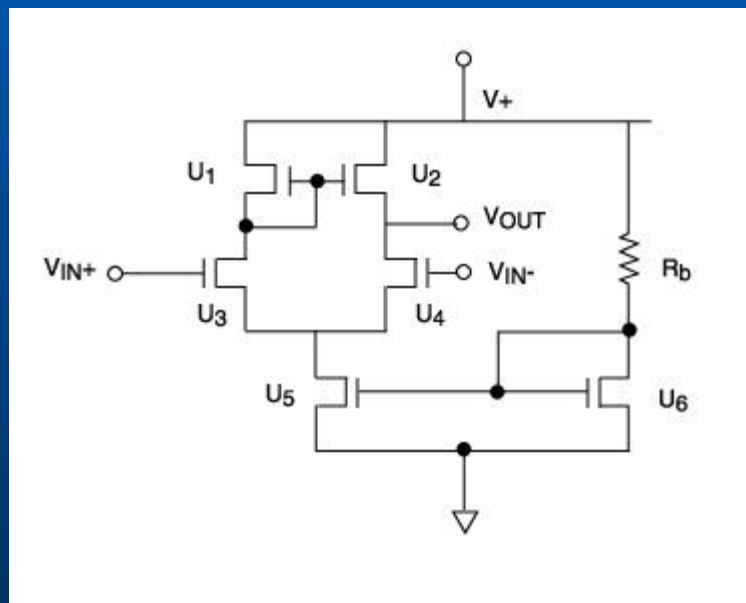
Free running oscillator running at 0.2V and nanowatt power



MOSFET Transistors

Example: Nanopower Differential Amplifier

Nanowatt Amplifier running on single +0.20V power supply





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Depletion Mode MOSFET Summary

Achieves industry first of -0.4V threshold voltage

- Threshold voltage precision to +/- 5mV
- Enable backup active circuits operating on zero standby power
- Enable many circuit function types previously not available
- Continues to push envelope of analog IC technology limits
- Industry's first EPAD[®] **Normally-On MOSFET**
- Breaks barriers in designing analog systems
- Enables new era of Zero-standby Power Systems

