



**QUAD/DUAL ELECTRICALLY PROGRAMMABLE ANALOG DEVICE (EPAD™)**

**FEATURES**

- Operates from 2V, 3V, 5V to 10V
- Flexible basic circuit building block and design element
- Very high resolution -- average programmable voltage resolution of 0.1mV
- Wide dynamic range -- current levels from 0.1µA to 3000µA
- Voltage adjustment range from 1.000V to 3.000V in 0.1mV steps
- Proven, non-volatile CMOS technology
- Typical 10 years drift of less than 2mV
- Usable in voltage mode or current mode
- High input impedance --  $10^{12}\Omega$
- Very high DC current gain -- greater than  $10^9$
- Device operating current has positive temperature coefficient range and negative temperature coefficient range with cross-over zero temperature coefficient current level at 68µA
- Tight matching and tracking of on-resistance between different devices with programming
- Very low input currents and leakage currents
- Low cost, monolithic technology
- Application-specific or in-system programming modes
- User programmable software-controlled automation
- User programmability of any standard/custom configuration
- Micropower operation
- Available in standard PDIP, SOIC and hermetic CDIP packages
- Suitable for matched-pair balanced circuit configuration
- Suitable for both coarse and fine trimming applications

**ORDERING INFORMATION**

Operating Temperature Range*		
-55°C to +125°C	0°C to +70°C	0°C to +70°C
16-Pin CERDIP Package	16-Pin Plastic Dip Package	16-Pin SOIC Package
ALD1108E DC	ALD1108E PC	ALD1108E SC

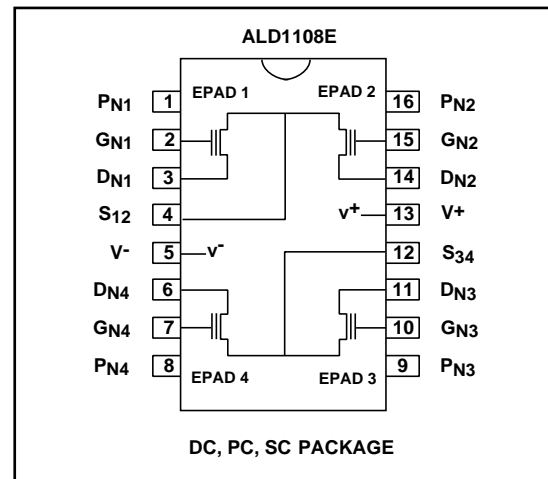
Operating Temperature Range*		
-55°C to +125°C	0°C to +70°C	0°C to +70°C
8-Pin CERDIP Package	8-Pin Plastic Dip Package	8-Pin SOIC Package
ALD1110E DA	ALD1110E PA	ALD1110E SA

\* Contact factory for industrial temperature range

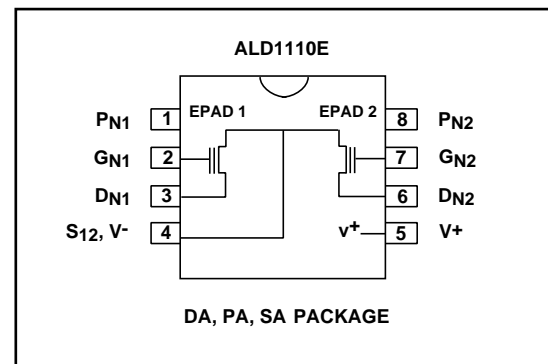
**BENEFITS**

- Simple, elegant single-chip solution to trimming voltage/current values
- Direct in-circuit active element operation and programming
- Remotely and electrically trim parameters on circuits that are physically inaccessible
- Usable in environmentally sealed circuits
- No system overhead or active circuitry required
- No mechanical moving parts -- high G-shock tolerance
- Improved reliability, dependability, dust and moisture resistance
- Cost and labor savings
- Small footprint for high board density applications
- Fully automated test and trimming environment

**PIN CONFIGURATION**



**PIN CONFIGURATION**



## APPLICATIONS

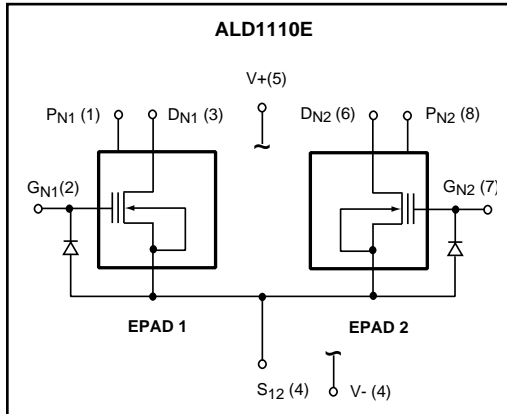
- Precision PC-based electronic calibration
- Automated voltage trimming or setting
- Remote voltage or current adjustment of inaccessible nodes
- PCMCIA based instrumentation trimming
- Electrically adjusted resistive load
- Temperature compensated current sources and current mirrors
- Electrically trimmed/calibrated current sources
- Permanent precision preset voltage level shifter
- Low temperature coefficient voltage and/or current bias circuits
- Multiple preset voltage bias circuits
- Multiple channel resistor pull-up or pull-down circuits
- Microprocessor based process control systems
- Portable data acquisition systems
- Battery operated terminals and instruments
- Remote telemetry systems
- Programmable gain amplifiers
- Low level signal conditioning
- Sensor and transducer bias currents
- Neural networks

## GENERAL DESCRIPTION

ALD1108E/ALD1110E are monolithic quad/dual EPADs (Electrically Programmable Analog Device) that utilize CMOS MOSFET with electrically programmable threshold voltage. For a given input voltage, changing the threshold turn-on voltage of a MOSFET device precisely changes its drain on-current, resulting in an on-resistance characteristic that can be precisely set and controlled. Used as an in-circuit element for trimming or setting a combination of voltage and/or current characteristics, it can be programmed via a Personal Computer remotely and automatically via software control. Once programmed and set, the set voltage and current levels are stored indefinitely inside the device as a precisely controlled nonvolatile stored charge, which is not affected during normal operation of the device, even after power has been turned off.

The ALD1108E/ALD1110E are devices built with ALD's EPAD technology, an electrically programmable device technology refined for analog applications. The ALD1108E/ALD1110E functions like a regular MOSFET transistor except with precise user preset threshold voltage. Using the ALD1108E/ALD1110E is simple and straight forward. The device is extremely versatile as a circuit element and design component. It presents the user with a wealth of possible applications, limited only by the imagination of the user and the many ways an analog MOSFET device can be used as a circuit design element. The ALD1108E/ALD1110E do not need other active circuitry for functionality.

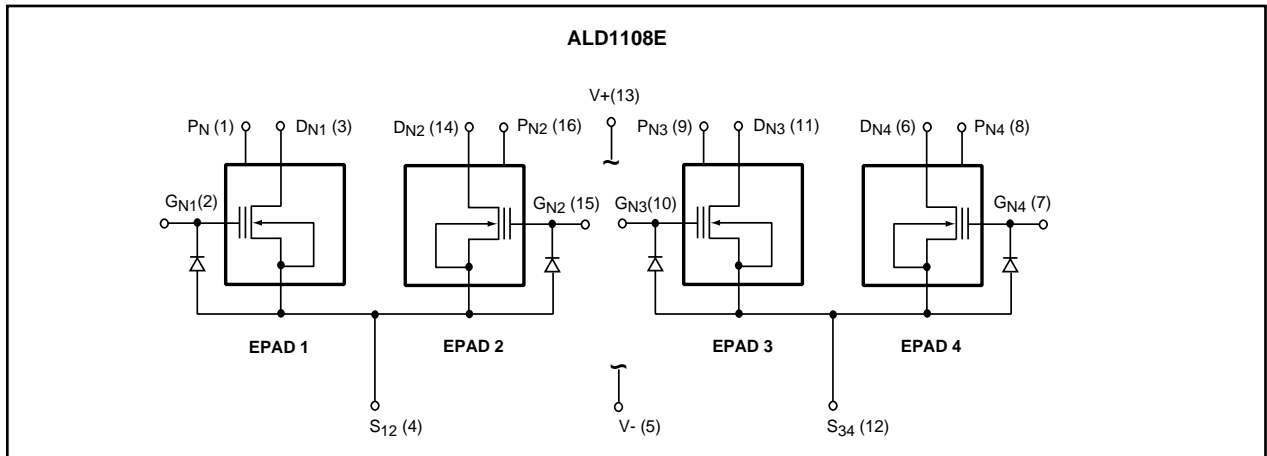
## BLOCK DIAGRAM



The basic device is a monotonically adjustable device which means the device can normally be programmed to increase in threshold voltage and to decrease in drain-on current as a function of a given input bias voltage. Once adjusted, the voltage and current conditions are permanent and not reversible. However, a given EPAD device can be adjusted many times to continually increase the threshold voltage. A pair of EPAD devices can also be connected such that one device is used to adjust a parameter in one direction and the other device is used to adjust the same parameter in the other direction.

The ALD1108E/ALD1110E can be pre-programmed with the ALD EPAD programmer to obtain the desired voltage and current levels. Or, they can be programmed as an active in-system element in a user system, via user designed interface circuitry. For more information, see Application Note AN1108.

## BLOCK DIAGRAM



### ABSOLUTE MAXIMUM RATINGS

Supply voltage, V<sup>+</sup> referenced to V<sup>-</sup> \_\_\_\_\_ -0.3V to +13.2V  
 Supply voltage, V<sub>S</sub> referenced to V<sup>-</sup> \_\_\_\_\_ ±6.6V  
 Differential input voltage range \_\_\_\_\_ 0.3V to V<sup>+</sup>+0.3V  
 Power dissipation \_\_\_\_\_ 600 mW  
 Operating temperature range PA, SA, PC, SC package \_\_\_\_\_ 0°C to +70°C  
 DA, DC package \_\_\_\_\_ -55°C to +125°C  
 Storage temperature range \_\_\_\_\_ -65°C to +150°C  
 Lead temperature, 10 seconds \_\_\_\_\_ +260°C

### OPERATING ELECTRICAL CHARACTERISTICS T<sub>A</sub> = 25°C V<sup>+</sup> = +5.0V unless otherwise specified

Parameter	Symbol	ALD1108E			ALD1110E			Unit	Test Conditions
		Min	Typ	Max	Min	Typ	Max		
Supply Voltage	V <sup>+</sup>	1.2		10.0	1.2		10.0	V	
Initial Threshold Voltage	V <sub>ti</sub>	0.990	1.000	1.010	0.990	1.000	1.010	V	I <sub>DS</sub> = 1μA T <sub>A</sub> = 21°C
Programmable V <sub>t</sub> Range	V <sub>t</sub>	1.000		3.000	1.000		3.000	V	
Drain - Gate Connected Voltage Tempco	TCV <sub>DS</sub>		-1.6 -0.3 0.0 +2.7			-1.6 -0.3 0.0 +2.7		mV/°C mV/°C mV/°C mV/°C	I <sub>D</sub> = 5μA I <sub>D</sub> = 50μA I <sub>D</sub> = 68μA I <sub>D</sub> = 500μA
Initial Offset Voltage	V <sub>OSi</sub>		1	5		1	5	mV	
Tempco of V <sub>OS</sub>	TCV <sub>OS</sub>		5			5		μV/°C	V <sub>DS1</sub> = V <sub>DS2</sub>
Differential Threshold Voltage	DV <sub>t</sub>			2.000			2.000	V	
Tempco of Differential Threshold Voltage	TCDV <sub>t</sub>		0.033			0.033		mV/°C	
Long Term Drift	ΔV <sub>t</sub> /Δt		-0.02	-0.05		-0.02	-0.05	mV	1000 Hours
Long Term Drift Match	ΔV <sub>t</sub> /Δt		-5			-5		μV	1000 Hours
Drain Source On Current	I <sub>DS(ON)</sub>		3.0			3.0		mA	V <sub>G</sub> = V <sub>D</sub> = 5V V <sub>S</sub> = 0V V <sub>t</sub> = 1.0
Drain Source On Current	I <sub>DS(ON)</sub>		0.8			0.8		mA	V <sub>G</sub> = V <sub>D</sub> = 5V V <sub>S</sub> = 0V V <sub>t</sub> = 3.0
Initial Zero Tempco Voltage	V <sub>ZTCi</sub>		1.52			1.52		V	V <sub>t</sub> = 1.000V
Zero Tempco Current	I <sub>ZTC</sub>		68			68		μA	
Initial On-Resistance	R <sub>ONi</sub>		500			500		Ω	V <sub>GSi</sub> = 5V V <sub>DS</sub> = 0.1V
On-Resistance Match	ΔR <sub>ON</sub>		0.5			0.5		%	

**OPERATING ELECTRICAL CHARACTERISTICS (cont'd)**  
**T<sub>A</sub> = 25°C V<sub>+</sub> = +5.0V unless otherwise specified**

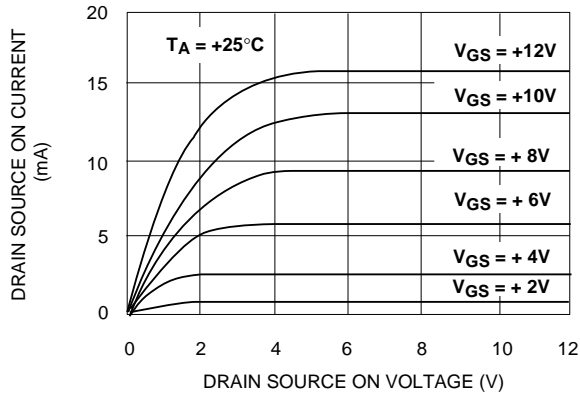
Parameter	Symbol	ALD1108E			ALD1110E			Unit	Test Conditions
		Min	Typ	Max	Min	Typ	Max		
Transconductance	gm		1.4			1.4		mA/V	V <sub>D</sub> = 10V, V <sub>G</sub> = V <sub>t</sub> + 4.0
Transconductance Match	Δgm		25			25		μA/V	V <sub>D</sub> = 10V, V <sub>G</sub> = V <sub>t</sub> + 4.0
Low Level Output Conductance	g <sub>OL</sub>		6			6		μA/V	V <sub>G</sub> = V <sub>t</sub> + 0.5V
High Level Output Conductance	g <sub>OH</sub>		68			68		μA/V	V <sub>G</sub> = V <sub>t</sub> + 4.0V
Drain Off Leakage Current	I <sub>D(OFF)</sub>		5	400 4		5	400 4	pA nA	T <sub>A</sub> = 125°C
Gate Leakage Current	I <sub>GSS</sub>		10	100 1		10	100 1	pA nA	T <sub>A</sub> = 125°C
Input Capacitance	C <sub>ISS</sub>		25			25		pF	
Cross Talk			60			60		dB	f = 100KHz
Relaxation Time Constant	t <sub>RLX</sub>		2			2		Hours	
Relaxation Voltage	V <sub>RLX</sub>		-0.3			-0.3		%	1.0V ≤ V <sub>t</sub> ≤ 3.0V

**PROGRAMMING CHARACTERISTICS**  
**T<sub>A</sub> = 25°C V<sub>+</sub> = +5.0V unless otherwise specified**

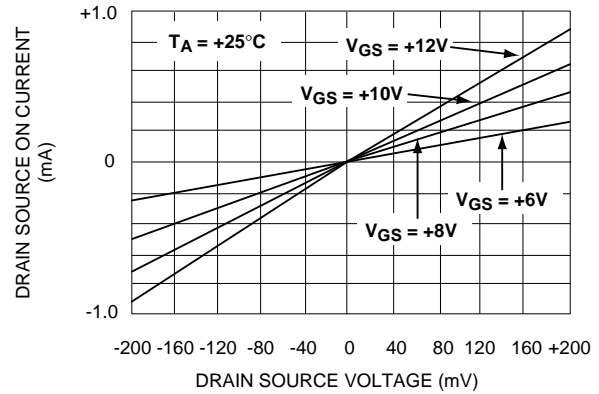
Parameter	Symbol	ALD1108E			ALD1110E			Unit	Test Conditions
		Min	Typ	Max	Min	Typ	Max		
Programmable V <sub>t</sub> Range	V <sub>t</sub>	1.000		3.000	1.000		3.000	V	
Resolution of V <sub>t</sub> Programming	RV <sub>t</sub>		0.1	1		0.1	1	mV	
Change in V <sub>t</sub> Per Programming Pulse	ΔV <sub>t</sub> / N		0.5 0.05			0.5 0.05		mV/ pulse	V <sub>t</sub> = 1.0V V <sub>t</sub> = 2.5V
Programming Voltage	V <sub>p</sub>	11.75	12.00	12.25	11.75	12.00	12.25	V	
Programming Current	I <sub>p</sub>		2			2		mA	
Pulse Frequency	f pulse		50			50		KHz	

# TYPICAL PERFORMANCE CHARACTERISTICS

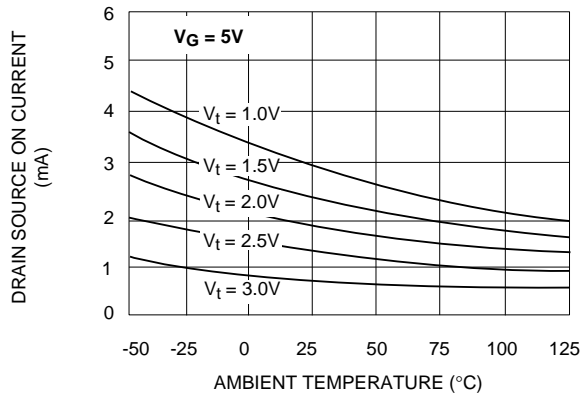
## OUTPUT CHARACTERISTICS



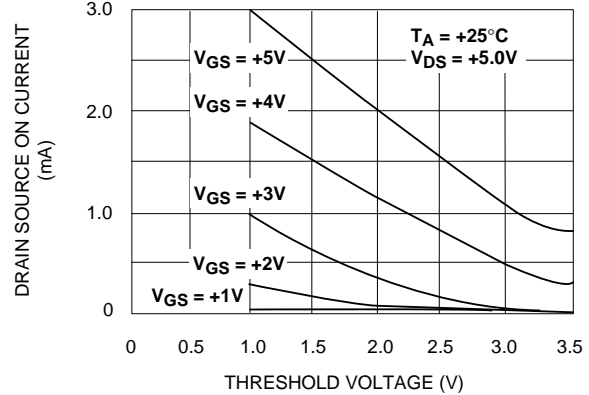
## OUTPUT CHARACTERISTICS



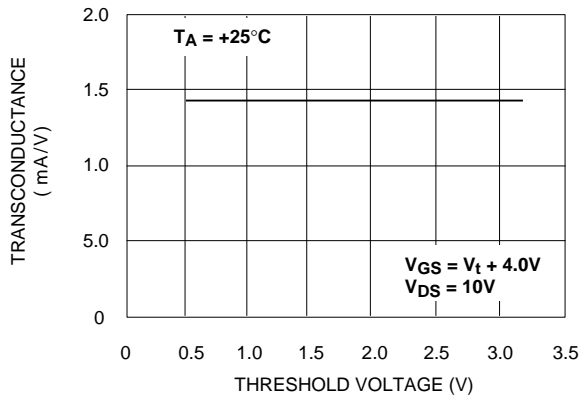
## DRAIN SOURCE ON CURRENT vs. AMBIENT TEMPERATURE



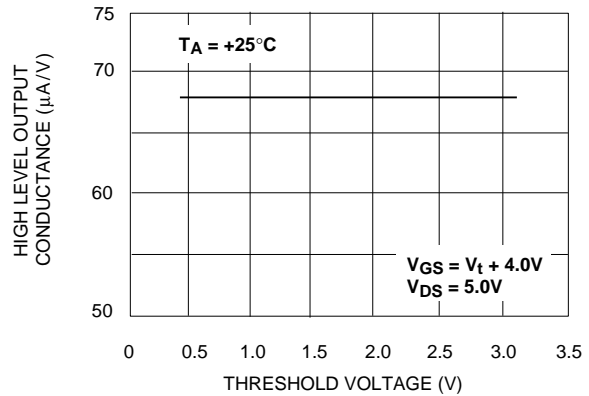
## DRAIN SOURCE ON CURRENT vs. THRESHOLD VOLTAGE



## TRANSCONDUCTANCE vs. THRESHOLD VOLTAGE

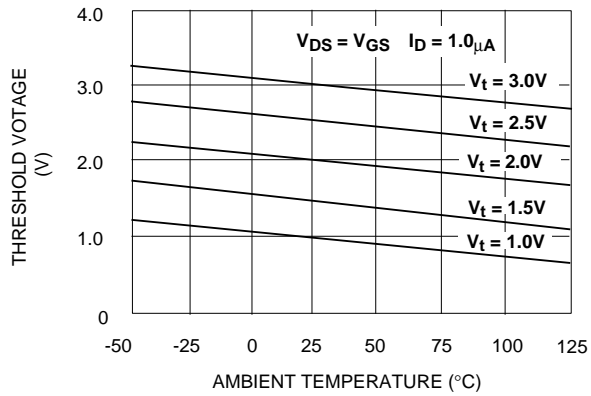


## HIGH LEVEL OUTPUT CONDUCTANCE vs. THRESHOLD VOLTAGE

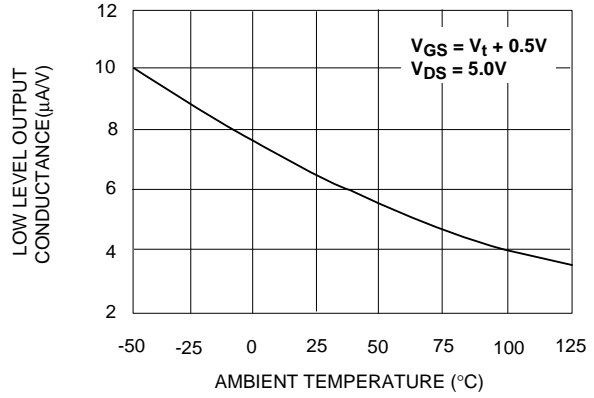


## TYPICAL PERFORMANCE CHARACTERISTICS

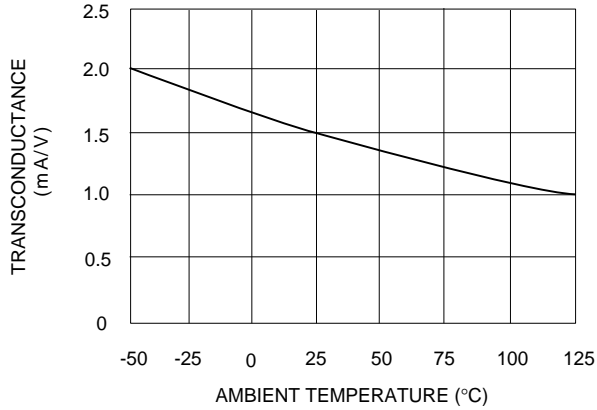
**THRESHOLD VOLTAGE vs. AMBIENT TEMPERATURE**



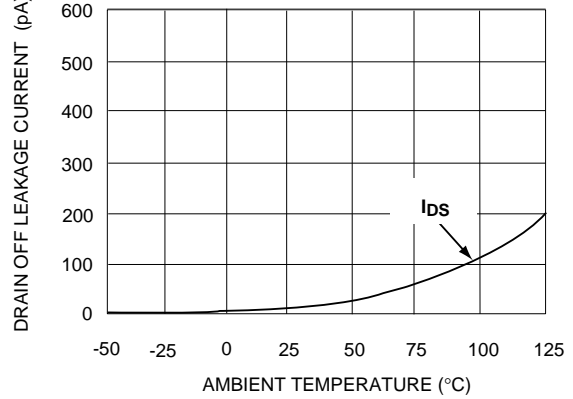
**LOW LEVEL OUTPUT CONDUCTANCE vs. AMBIENT TEMPERATURE**



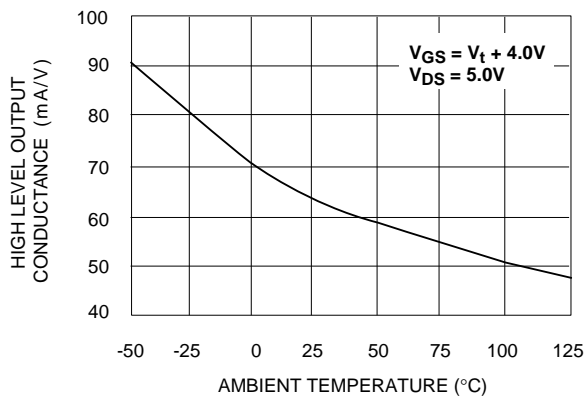
**TRANSCONDUCTANCE vs. AMBIENT TEMPERATURE**



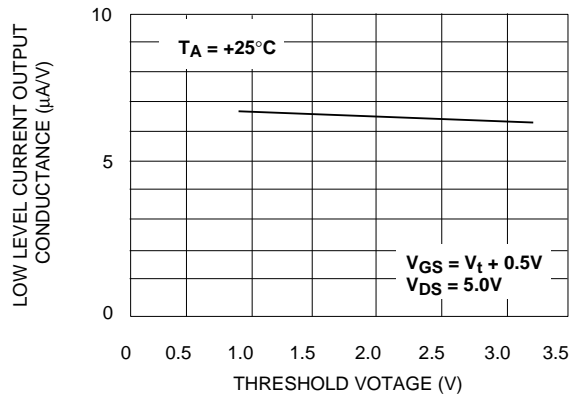
**DRAIN OFF LEAKAGE CURRENT  $I_{DS}$  vs. AMBIENT TEMPERATURE**



**HIGH LEVEL OUTPUT CONDUCTANCE vs. AMBIENT TEMPERATURE**

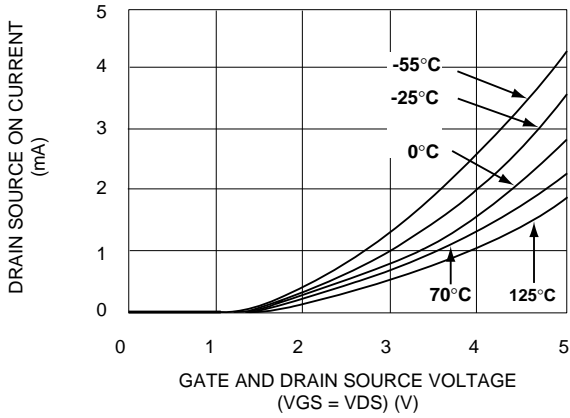


**LOW LEVEL OUTPUT CONDUCTANCE vs. THRESHOLD VOLTAGE**

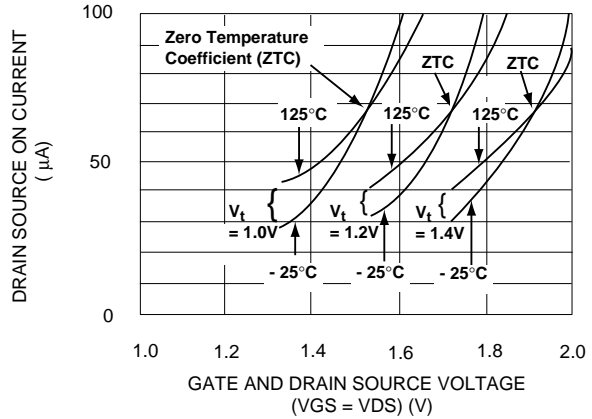


# TYPICAL PERFORMANCE CHARACTERISTICS

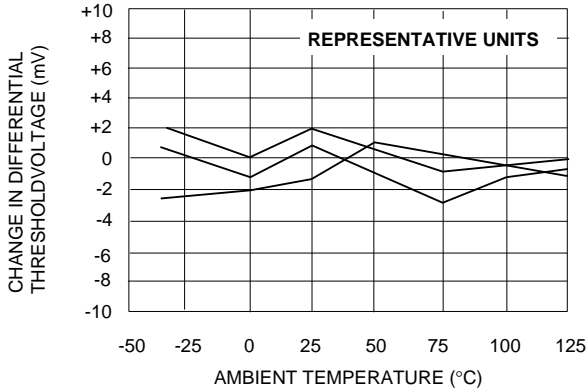
**DRAIN SOURCE ON CURRENT, BIAS CURRENT vs. AMBIENT TEMPERATURE**



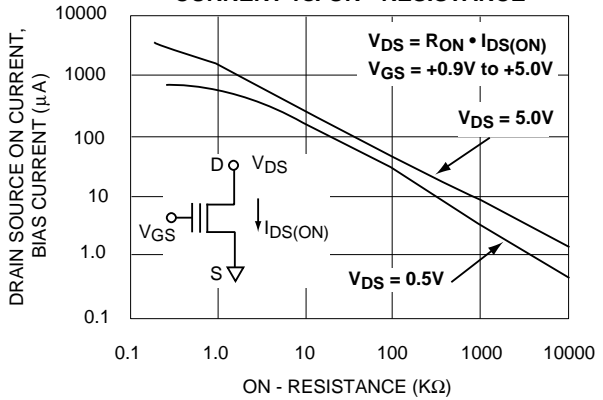
**DRAIN SOURCE ON CURRENT, BIAS CURRENT vs. AMBIENT TEMPERATURE**



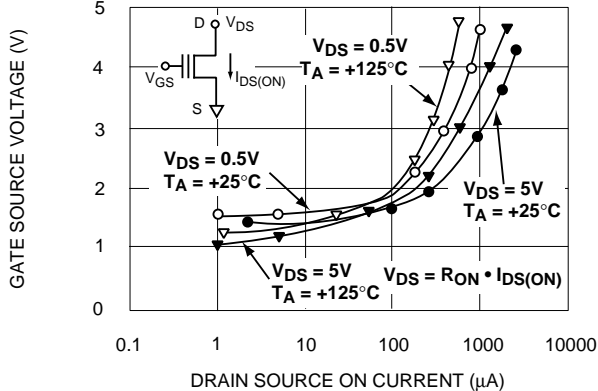
**CHANGE IN DIFFERENTIAL THRESHOLD VOLTAGE vs. AMBIENT TEMPERATURE**



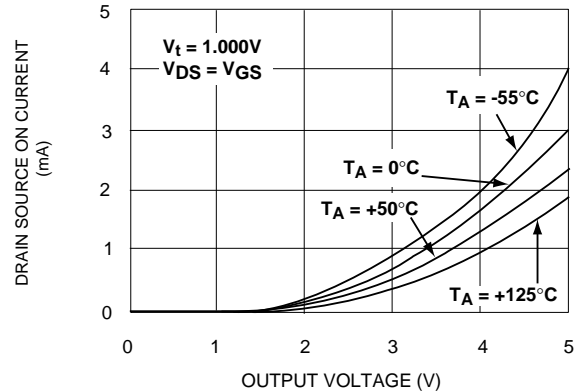
**DRAIN SOURCE ON CURRENT, BIAS CURRENT vs. ON - RESISTANCE**



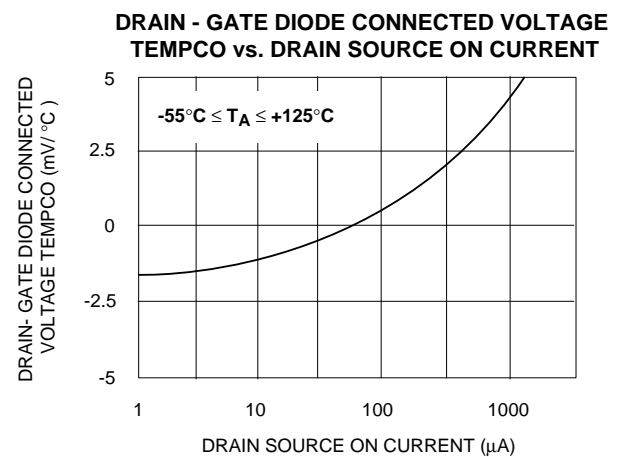
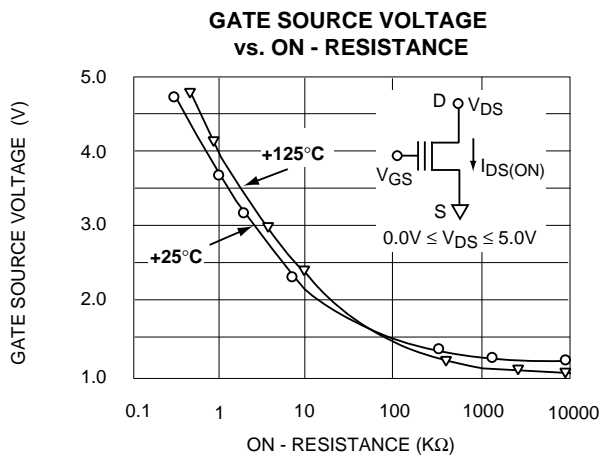
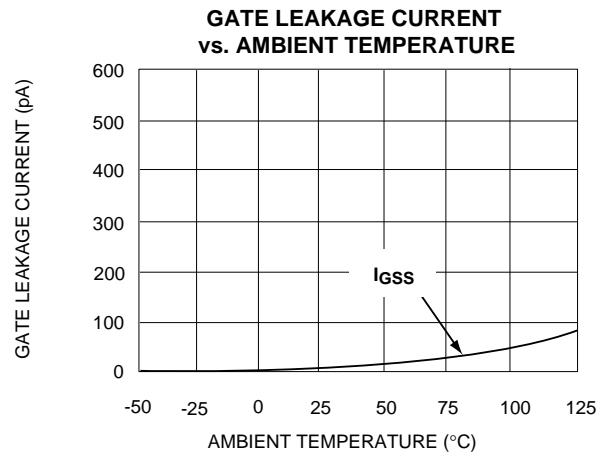
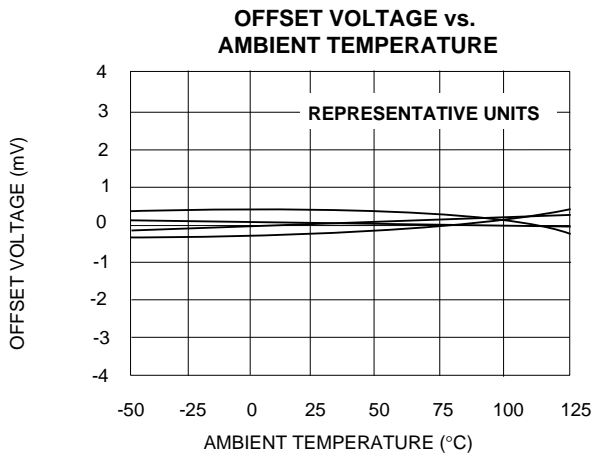
**GATE SOURCE VOLTAGE vs. DRAIN SOURCE ON CURRENT**



**DRAIN SOURCE ON CURRENT vs. OUTPUT VOLTAGE**



## TYPICAL PERFORMANCE CHARACTERISTICS





## DEFINITION OF TERMS

### Bias Voltage ( $V_{BIAS}$ )

Bias Voltage of an EPAD is the voltage across Gate and Source terminals with Gate and Drain connected at a specified Drain to Source Current,  $I_{DS}$ . When  $I_{DS} = 1\mu A$ , Bias Voltage is identical to Threshold Voltage. Input Bias Voltage of an EPAD is the voltage across Gate and Source terminals,  $V_{GS}$ . Output Bias Voltage of an EPAD is the voltage across Drain and Source terminals  $V_{DS}$  at a specified Drain to Source Current,  $I_{DS}$ .

### Change in Threshold Voltage Per Programming Pulse ( $\Delta V_t / N$ )

This is the voltage change in Threshold Voltage while the EPAD is being programmed with an electrical voltage pulse. This voltage change can be very small as it varies as an exponential function of  $V_t$ . Typical initial values range from 0.1 mV/step to 1.0mV/step when  $V_t = 1$  Volt and decreases to 10 $\mu$ V/step or lower at higher  $V_t$  values.

### Delta Threshold Voltage ( $\Delta V_t$ )

Delta Threshold Voltage is a change in the threshold voltage of the same EPAD device after programming.

### Differential Threshold Voltage ( $DV_t$ )

Differential Threshold Voltage is the difference of  $V_t$  between the two EPAD devices, each electrically programmed to a different  $V_t$  value. This is also a fixed relative voltage that tracks with temperature, with tempco value of TC  $DV_t$  for 1 volt relative  $V_t$  between two EPADs.

## EPAD™

Electrically Programmable Analog Device is an Integrated Circuit that utilizes CMOS FET with electrically programmable Threshold Voltage. Once programmed, the set Threshold Voltage is retained indefinitely, even when power is off.

### Initial Threshold Voltage ( $V_{ti}$ )

The initial  $V_t$  of a device before being electrically programmed to a new  $V_t$  value.

### Initial Zero Tempco Voltage ( $V_{ZTCi}$ )

Initial Drain Voltage at which the Temperature Coefficient of the Drain-Gate connected Voltage, relative to the Source Voltage, is at zero, when the initial  $V_t$  is at 1.000 volt.

### Long Term Drift ( $\Delta V_t / \Delta t$ )

Long Term Drift is the nominal change in threshold voltage of an EPAD for a time period of 1,000 hours.

### Long Term Drift Match ( $\Delta V_t / \Delta t$ )

Long Term Drift Match is the nominal match in long term drift between two EPADs, for a time period of 1,000 hours.

### Monotonic Adjustment of $V_t$

$V_t$  Adjustment can be changed in one direction only.

### Offset Voltage ( $V_{OS}$ )

Offset Voltage is the small difference in  $V_t$  between two EPAD devices when the two devices have the same initial electrically programmed  $V_t$  values.

### Programming Voltage ( $V_p$ )

The voltage at which programming of the threshold voltage of the EPAD occurs. This voltage, the control of timing of this voltage and the impedance of the voltage source is critical to the way the EPAD is programmed and its subsequent device performance. The user is advised to use an ALD EPAD programmer which has been specifically designed and developed for this task.

### Relaxation Time Constant ( $t_{RLX}$ )

Relaxation Time Constant is the time constant associated with the Relaxation Voltage drop after an EPAD has been programmed.

**Relaxation Voltage ( $V_{RLX}$ )**

After programming, an EPAD threshold voltage will “relax” a small amount, which corresponds to a small loss of interface charge. This is a small, fixed voltage step and decreases at a Relaxation Time Constant. The Relaxation Voltage is the voltage change (voltage drop) after three Relaxation Time Constants. To compensate for this, an initial relaxation voltage, expressed as a percentage of the programmed  $V_t$ , can be added to the initial desired target voltage.

**Tempco of Differential Threshold Voltage ( $TCDV_t$ )**

Temperature Coefficient of Differential Threshold Voltage is the change in difference between two EPAD threshold voltages per degree C change in temperature when the two devices initially have 1V relative electrically programmed  $V_t$  difference.

**Tempco of Threshold Voltage ( $TCV_t$ )**

Temperature Coefficient of the  $V_t$  is the change in the Threshold Voltage per degree C change in temperature.

**Threshold Voltage ( $V_t$ )**

Threshold Voltage of an EPAD is the voltage across Gate and Source when  $1\mu A$  is forced into the Drain terminal as the Drain and Gate are connected together.

**Tempco of  $V_{OS}$  ( $TCV_{OS}$ )**

Temperature Coefficient of Offset Voltage is the change in difference between two EPAD threshold voltages per degree Centigrade change in temperature when the two devices have the same initial electrically programmed  $V_t$  values.

**Zero Tempco Current ( $I_{ZTC}$ )**

The Drain current of an EPAD device at which Temperature Coefficient of the Drain-Gate Connected Voltage, relative to the Source Voltage, is at zero.