

# TOTALLY RE-CONFIGURABLE ANALOG CIRCUIT - TRAC<sup>®</sup>

**TRAC020LH**

**Issue 2 - MARCH 1999**

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## DEVICE DESCRIPTION

The TRAC020LH is a Micro-Power version of the existing TRAC products. It also offers significant improvements in bandwidth and function accuracy.

The TRAC020LH is the latest addition to the TRAC family of Field Programmable Analog Devices (FPAD) which offers an integrated path from signal processing problems to working silicon solutions - in minutes! The Totally Reconfigurable Analog Circuit is a highly flexible single chip solution to the signal processing problems found in many markets.

Introducing a Top-Down, Structured design discipline, TRAC enables rapid implementation, prototyping and product release. Rather than working at the component level, TRAC champions the Computational Approach, providing designers with benefits formerly associated with programmable digital devices. TRAC brings a truly integrated Signal Processing problem solving process and offers a path to Custom Silicon for high volume applications.

## APPLICATIONS

Many analog signal processing applications including:-

- Analog Computation
- Analog Signal Processing (ASP)
- Classical & Modern Control Systems
- Audio Applications
- Sonar and Ultrasonic Systems
- Analog Correlation
- Echo Cancellation

- Log, Linear and Modern Filter Design
- Instrumentation
- Transducer Characteristic Correction
- Vector Analysis

## FEATURES AND BENEFITS

- Faster design and verification of signal processing solutions
- Instant working silicon
- Flexibility to react to changing requirements
- Stay thinking about analog problems mathematically - minimal circuit design
- Just as versatile as FPGA - and just as easy
- Complete more projects on time
- High level of integration and design secrecy
- Integration with other CAE systems
- Transparent design migration to semi-custom and future devices
- Less than 8 bytes to program
- Full industrial temperature range
- Standby mode for improved battery life
- Devices easily cascaded for more complex designs
- Combines silicon, software and support

## ORDERING INFORMATION

PART NUMBER	PACKAGE	PART MARK
TRAC020LHQ36	QSOP36	TRAC020LH

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# TRAC020LH

## ABSOLUTE MAXIMUM RATINGS

Voltage on any pin = 7.0V (relative to  $V_{SS}$ )

Operating Temperature = -40 to 85°C

Storage Temperature = -55 to 125°C

## GENERAL ELECTRICAL CHARACTERISTICS

Test Conditions: Temperature = 25 °C,  $V_{DD} = 3.0V \pm 0.15V$ ,  $V_{SS} = -2.0V \pm 0.10V$

PARAMETER	CONDITIONS	MIN	TYPICAL	MAX
General Characteristics				
Dynamic Range			80dB	
Noise Voltage	10Hz-100kHz		$15nV/\sqrt{Hz}$	
Total Harmonic Distortion	100mV peak-peak 1.0V peak-peak		0.02% 0.08%	
Intermodulation Distortion			< 0.1%	
Supply Rejection			60dB	
Cell to cell crosstalk			-60dB	
Input Range (all IO pins)			$V_{DD}-2.0V$ , $V_{SS}+1.0V$	
Slew Rate			4V/ $\mu$ S	
Supply Current				
Operating Current $I_{DD}$	Cells to NIP function $\overline{PD}=V_{DD}$	2.5mA	5.0mA	6.0mA
Operating Current $I_{SS}$		-2.5mA	-5.0mA	-6.0mA
Shutdown Current $I_{DD}$	$\overline{PD}=V_{SS}$			10 $\mu$ A
Cell Output Capability				
Sink Current			150 $\mu$ A	
Source Current			150 $\mu$ A	

# TRAC020LH

## ELECTRICAL CHARACTERISTICS OF THE CELL

Test Conditions: Temperature = 25 °C,  $V_{DD} = 3.0V \pm 0.15V$ ,  $V_{SS} = -2.0V \pm 0.10V$

FUNCTION	PARAMETER	CONDITIONS	MIN	TYPICAL	MAX
Non Inverting Pass	Gain	$V_{in} = \pm 800mV$	0.996	1.000	1.004
	Input Resistance			60M $\Omega$	
	Offset	$V_{in}=0mV$	-1.2mV	0mV	1.2mV
	Input Current			100nA	260nA
	Bandwidth (small signal)	20mV peak-peak		12MHz	
	Bandwidth (large signal)	500mV peak-peak		3MHz	
Negate	Gain	$V_{in} = \pm 800mV$	-1.010	-1.000	-0.990
	Input Resistance		30k $\Omega$	40k $\Omega$	50k $\Omega$
	Offset	$V_{in}=0mV$	-2.4mV	0mV	2.4mV
	Bandwidth (small signal)	20mV peak-peak		7MHz	
	Bandwidth (large signal)	500mV peak-peak		3MHz	
Add	Gain	$V_A=V_B = \pm 400mV$	-1.012	-1.000	-0.988
	Input Resistance		30k $\Omega$	40k $\Omega$	50k $\Omega$
	Offset	$V_{in}=0mV$	-3.4mV	0mV	3.4mV
	Bandwidth (small signal)	20mV peak-peak		6MHz	
	Bandwidth (large signal)	500mV peak-peak		3MHz	
Log	Output Voltage	$V_{in} = \pm 1.000V$	$\pm 625$ mV	$\pm 685$ mV	$\pm 745$ mV
	Transfer Characteristic (Change in output for a 10x change in input voltage)	$V_{in} = \pm 10mV, \pm 100mV, \pm 1000mV$		$\pm 60mV$	
	Input Resistance		30k $\Omega$	40k $\Omega$	50k $\Omega$
Auxiliary	Gain	$R_F = R_S = 20k\Omega,$		-0.993	
	Input Current	$R_F = R_S = 20k\Omega,$ $V_{in} = 0$ mV		100nA	
	Offset	$R_F = R_S = 20k\Omega,$ $V_{in} = 0$ mV		2.0mV	
	Output Saturation Voltage	$V_{in} = \pm 50mV$	$< V_{SS} + 0.2V$		$> V_{DD} - 1.7V$
	Open Loop		300	700	

# TRAC020LH

## ELECTRICAL CHARACTERISTICS OF THE CELL (Continued)

Test Conditions: Temperature = 25 °C,  $V_{DD} = 3.0V \pm 0.15V$ ,  $V_{SS} = -2.0V \pm 0.10V$

FUNCTION	PARAMETER	CONDITIONS	MIN	TYPICAL	MAX
Alog	Output Voltage	$V_{in} = \pm 685mV$	$\pm 0.80V$	$\pm 1.00V$	$\pm 1.2V$
	Transfer Characteristic (Multiplication of the output voltage for fixed steps in input voltage)	$V_{in} = \pm 565mV, \pm 625mV, \pm 685mV$ steps		$\pm 10$	
Rectify	Output Voltage	$V_{in} = -685mV$ $V_{in} = 685mV$	+0.80V -5.0mV	+1.00V	+1.2V 5.0mV
	Transfer Characteristic (Multiplication of the output voltage for fixed steps in input voltage)	$V_{in} = -565mV, -625mV, -685mV$ steps		+10	
Off	Attenuation	$V_{in} = \pm 1.0V$	-60dB	-80dB	
LOG/ALOG	Gain	$V_{in} = \pm 1.0V$		1.00	
	Bandwidth (small signal)	20mV peak-peak		6MHz	
	Bandwidth (large signal)	500mV peak-peak		2MHz	
LOG/REC	Gain	$V_{in} = \pm 1.0V$		1.00	
	Bandwidth (small signal)	20mV peak-peak		6MHz	
	Bandwidth (large signal)	500mV peak-peak		2MHz	

## ELECTRICAL CHARACTERISTICS OF THE LOGIC FUNCTIONS ( $V_{DD} - V_{SS} = 5.0V \pm 0.25V$ )

FUNCTION	CONDITIONS	MIN	TYPICAL	MAX
(VOH (for output pins DOUT, CLCR )	$IOH = -4mA$	4.0V (WRT $V_{SS}$ )		5.0V (WRT $V_{SS}$ )
VOL (for outputs DOUT, CLCR	$IOH = 4mA$	0.0V (WRT $V_{SS}$ )		0.4V (WRT $V_{SS}$ )
I <sub>IH</sub> (for inputs DATA CLOCK, RESET, PD )	$VIH = 5V$ (WRT $V_{SS}$ )			1.0 $\mu$ A
I <sub>IL</sub> (for inputs DATA CLOCK, RESET, PD )	$VIL = 0V$ (WRT $V_{SS}$ )	-1.0 $\mu$ A		
Max. CLOCK frequency			10MHz	

## DESCRIPTION OF PIN FUNCTIONS

<b>DATA</b>	Serial programming data is input to the TRAC via this pin. Each TRAC cell contains a 3-bit shift register that allows each cell to be programmed to the required analog function.
<b>RESET</b>	Active low - The pin resets all on-chip shift registers to the logic zero state, which sets all TRAC cells to the OFF function. The pin should be held high while the device is being programmed and when the analog functions are in use.
<b>PD</b>	Active low - The pin switches off the bias generators to the analog cells, which turns off the supply current to all the TRAC cells. This does not influence the programming of the cells so this feature can be used to reduce power consumption for applications that have a standby mode. The pin should be held high while the device is being programmed and when the analog functions are in use. This pin is permanently held high ( $V_{DD}$ ) on the TRAC development board.
<b>CLOCK</b>	Used to clock in the serial data to program the TRAC device. The on-chip shift registers are positive edge triggered.
<b>DOUT</b>	This pin is the serial data output from cell 20 on the TRAC device. This is used for validation of programming of the TRAC device. This pin also allows two or more TRAC devices to be connected in a serial architecture. This is done by connecting the DOUT pin of the first TRAC device to the DATA pin of the second TRAC device, and connecting the CLOCK pins.
<b>CLCR</b>	Clock Clear. When the TRAC device is used in stand alone applications CLCR is used as a control pin. It allows the downloading circuitry to be switched off when the programming serial data from the EEPROM is complete.
<b>IO3..IO22</b>	These are the analog inputs / outputs for cells 1 to 20.
<b>IO1,IO2</b>	These are the analog inputs for cells 1 and 2.
<b>V<sub>DD</sub></b>	TRAC positive supply rail (+3V)
<b>A<sub>GND</sub></b>	Analog Ground
<b>V<sub>SS</sub></b>	TRAC negative supply rail (-2V) - this will also be the system ground

# TRAC020LH

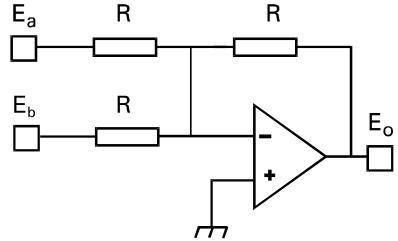
## CELL FUNCTION DETAILS

### ADD (code 011)

Can be represented as an operational amplifier with three resistors of equal value R. The virtual earth at the inverting input gives:-

$$E_o = -R(E_a/R + E_b/R) = -(E_a + E_b)$$

The output is the inverted sum of the input voltages.



### NEGATE (code 010)

The negate function is provided by an adder, but with only one input, therefore  $E_o = -E_b$

### NON INVERTING PASS (code 100)

Used for topological reasons. It provides a route through the cell with no modification. i.e. a unity gain amplifier

### LOG (code 110)

Can be represented as an operational amplifier with a pair of back to back diodes in the negative feedback loop and an input resistor R. The virtual earth at the inverting input gives:-

$$E_o = -kT/q \log (E_a/R I_o + 1)$$

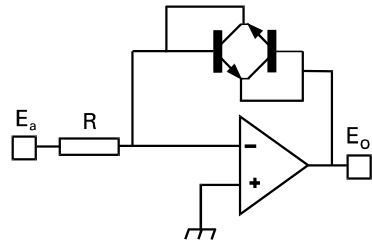
where

k = Boltzmann's constant

T = absolute temperature

q = electron charge

$I_o$  = saturation current

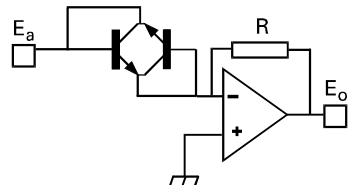


### ANTI - LOG (code 101)

Similar to the log circuit except that the diodes and resistors are reversed. The output voltage is therefore given as :-

$$E_o = -R I_o (\exp qE_a/KT - 1)$$

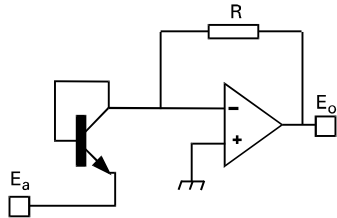
When the signal is processed through both log and anti-log the magnitude of the saturation current and absolute temperature cancel.



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**CELL FUNCTION DETAILS (Continued)**  
**RECTIFIER (code 111)**

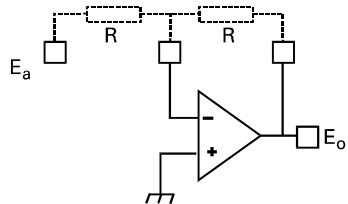
Similar to the anti-log function except that one of the diodes is removed so that a positive input gives zero output.



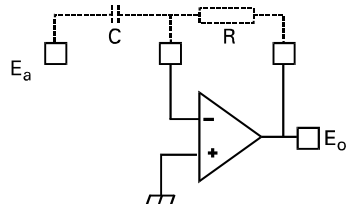
**AUX (code 001)**

As for an operational amplifier external components are used to provide the following functions - external components are shown dotted

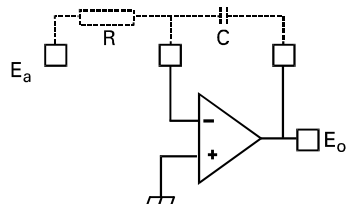
Amplification  
 Attenuation



Differentiation



Integration



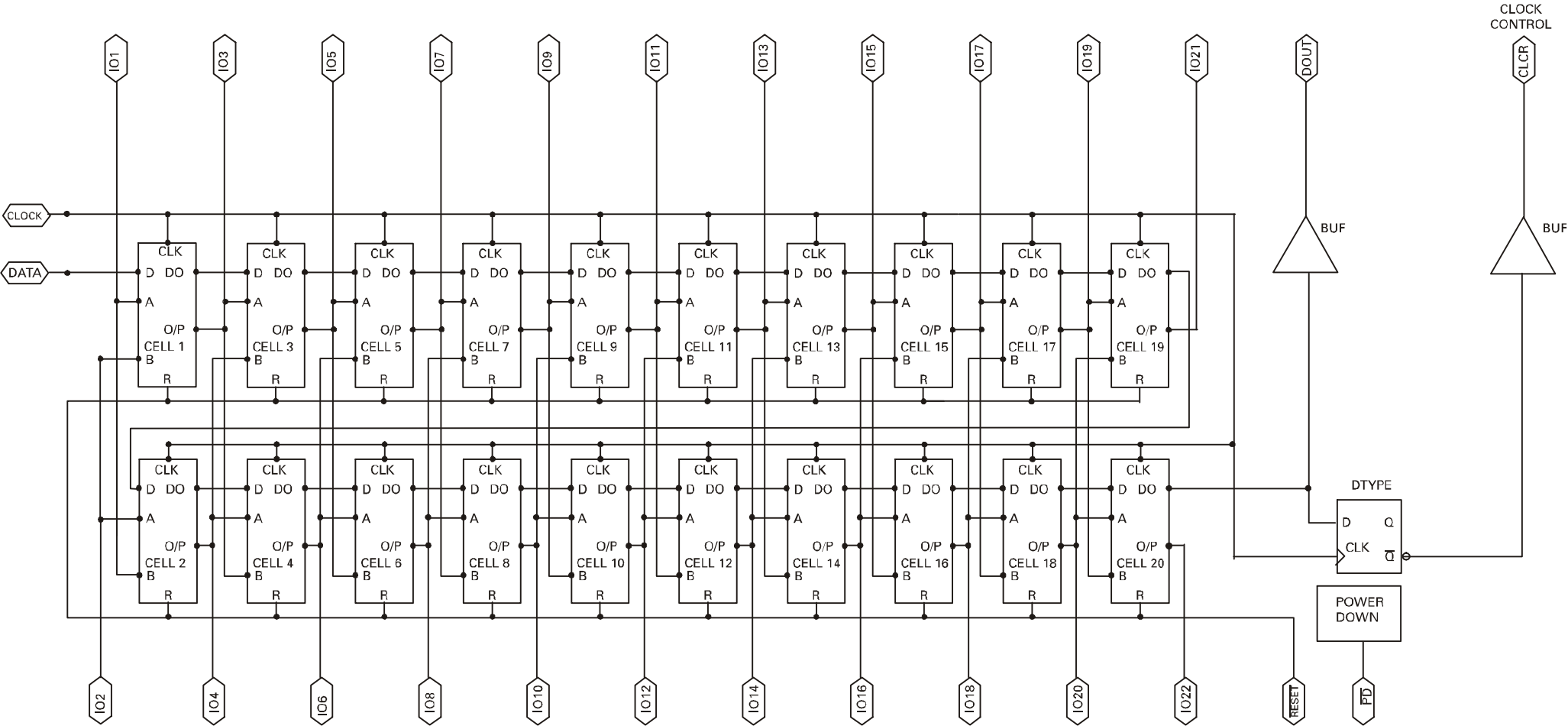
**OFF (code 000)**

In the off condition there is no signal path through the cell.

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SCHMATIC DIAGRAM



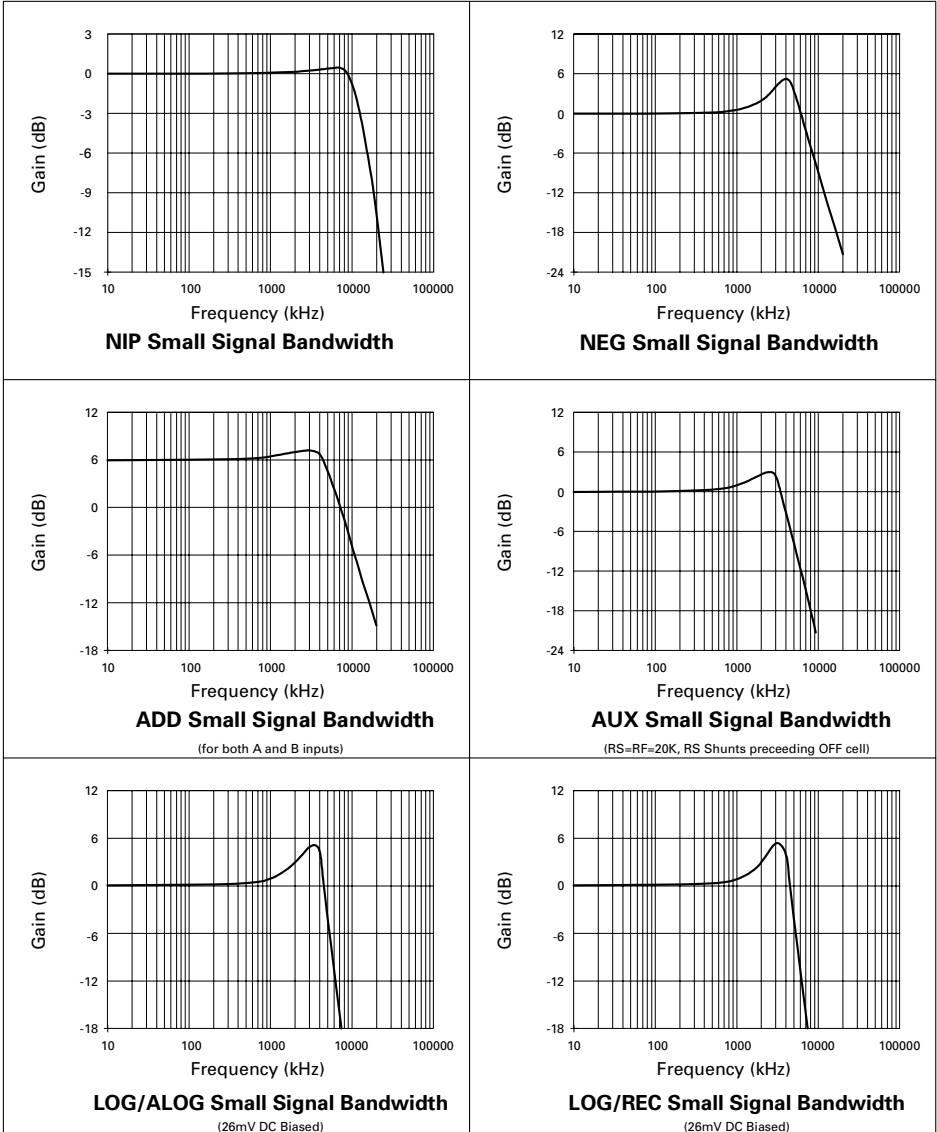


# TRAC020LH

## TYPICAL ELECTRICAL CHARACTERISTICS

### Cell Frequency Responses, Small Signal Amplitude 20mV Pk-Pk

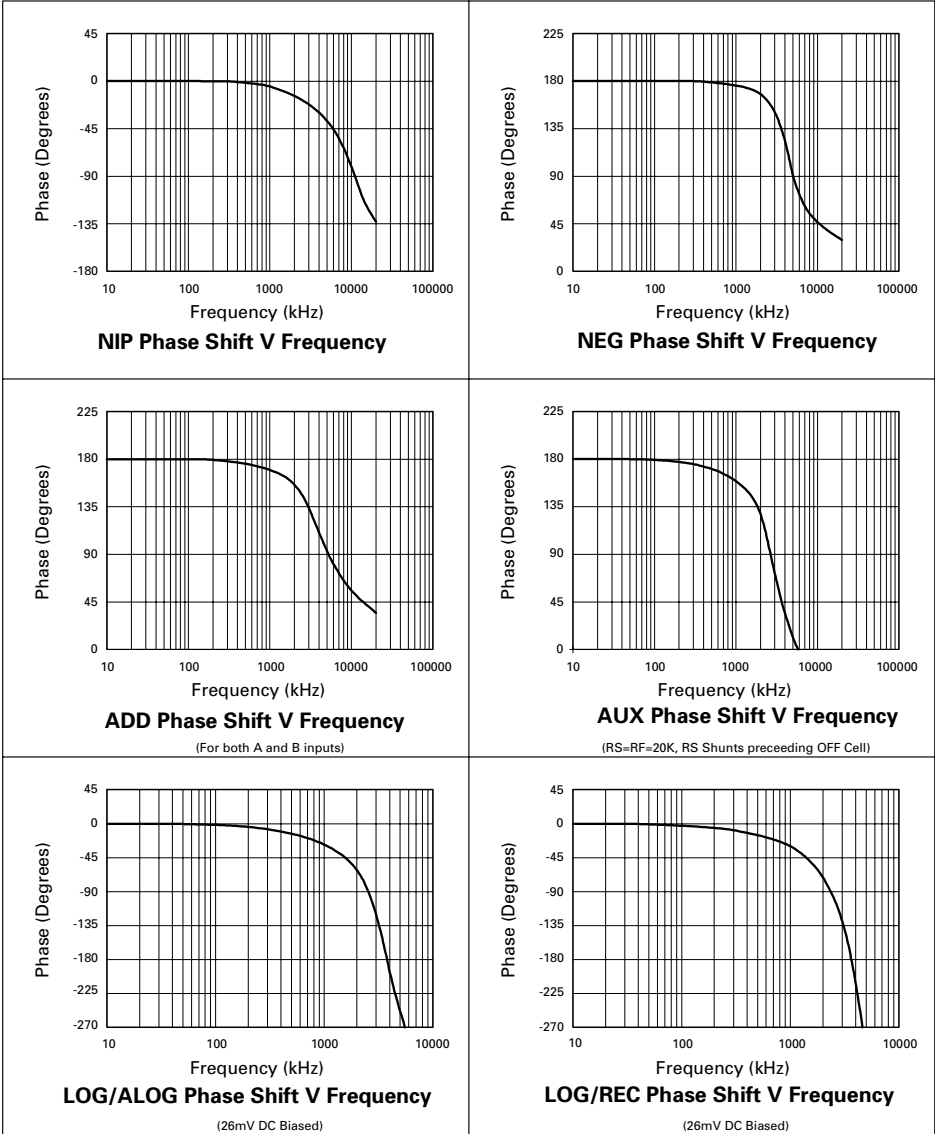
Test Conditions: Temperature = 25 °C,  $V_{DD} = 3.0V \pm 0.15V$ ,  $V_{SS} = -2.0V \pm 0.10V$



# TRAC020LH

**TYPICAL ELECTRICAL CHARACTERISTICS**  
**Cell Phase Delay, Small Signal Amplitude 20mV Pk-Pk**

Test Conditions: Temperature = 25 °C,  $V_{DD} = 3.0V \pm 0.15V$ ,  $V_{SS} = -2.0V \pm 0.10V$

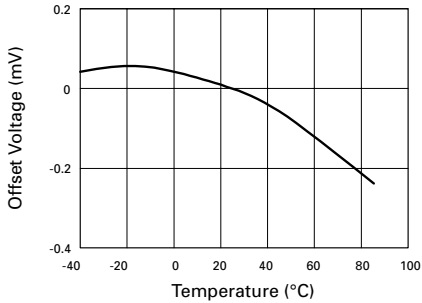


# TRAC020LH

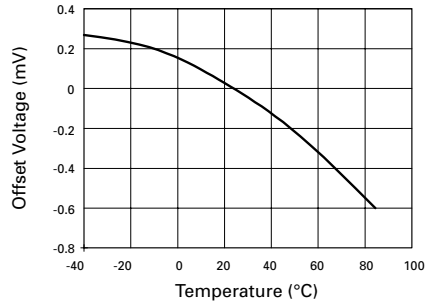
## TYPICAL ELECTRICAL CHARACTERISTICS

### Cell Offset Voltage against Temperature Characteristics Test Conditions:

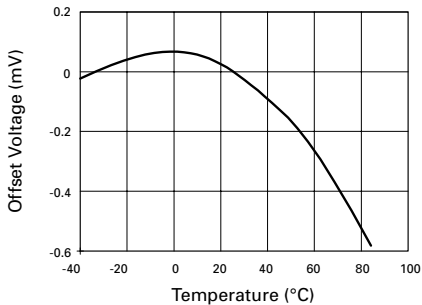
Temperature = 25 °C,  $V_{DD} = 3.0V \pm 0.15V$ ,  $V_{SS} = -2.0V \pm 0.10V$



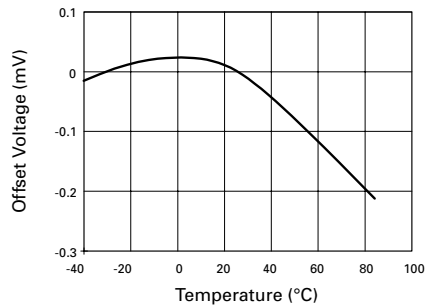
**NIP Offset Voltage V Temp.**



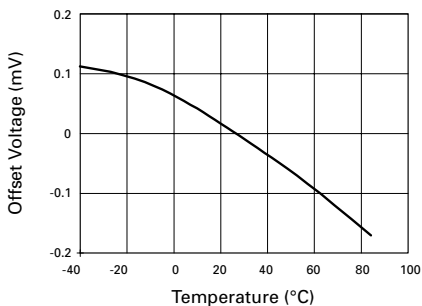
**NEG Offset Voltage V Temp.**



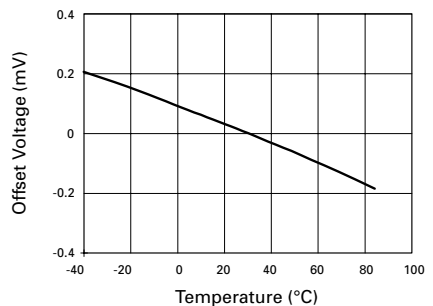
**ADD Offset Voltage Vs Temp.**



**AUX Offset Voltage V Temp.**



**LOG/ALOG Offset Voltage V Temp.**

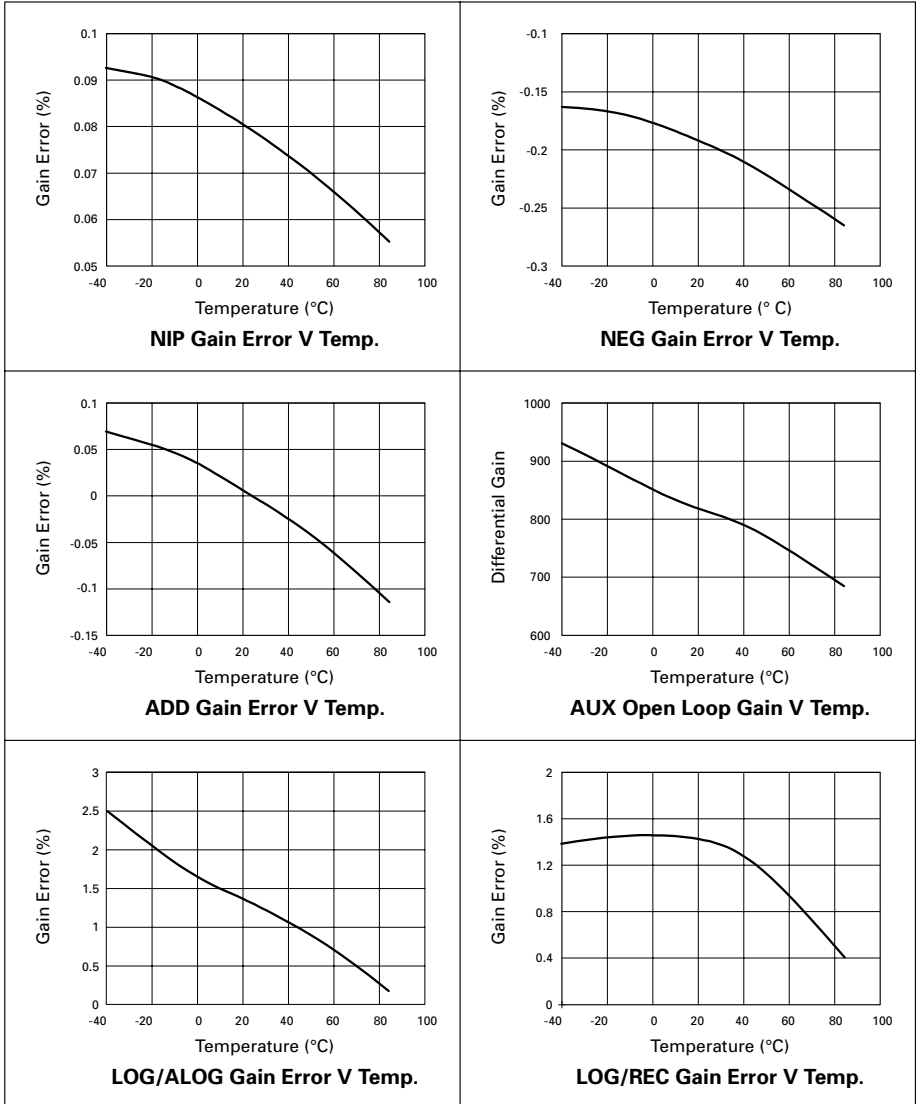


**LOG/REC Offset Voltage V Temp.**

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## TYPICAL ELECTRICAL CHARACTERISTICS Cell Voltage Gain against Temperature Characteristics

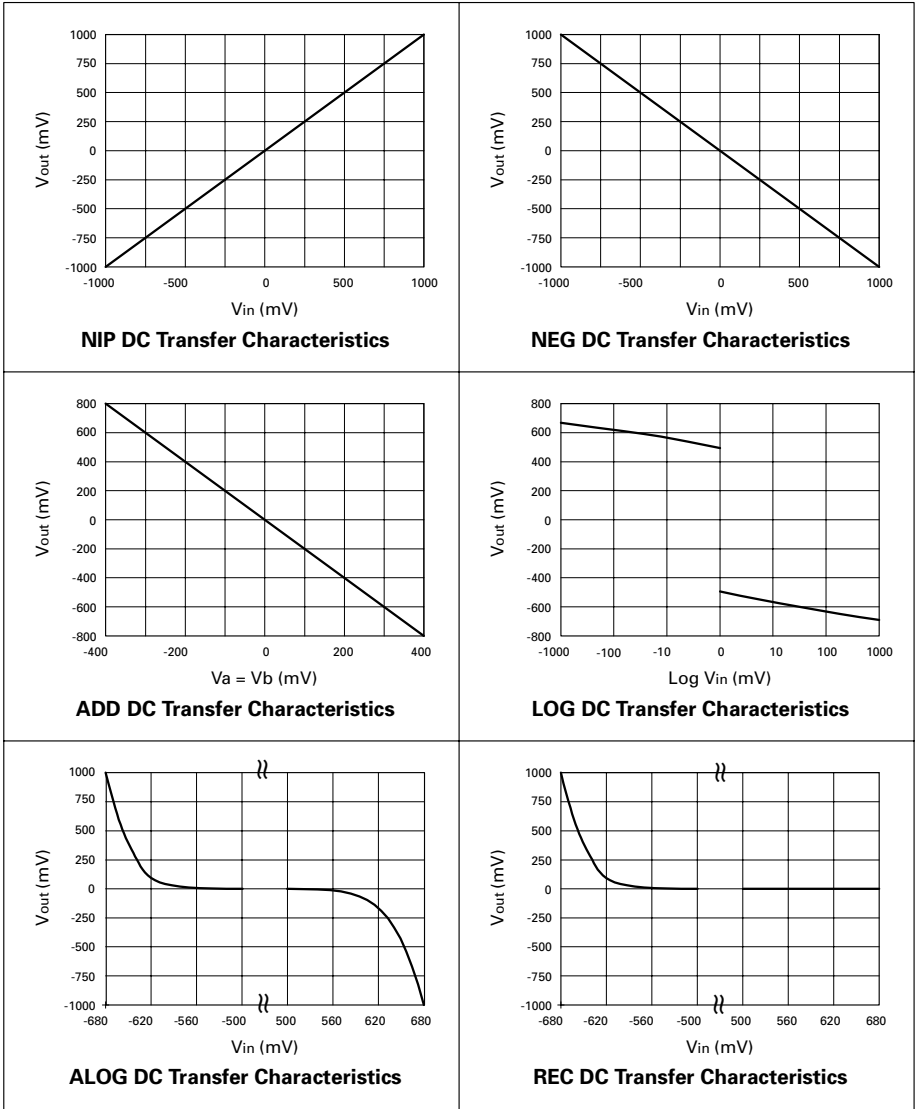
Test Conditions: Temperature = 25 °C,  $V_{DD} = 3.0V \pm 0.15V$ ,  $V_{SS} = -2.0V \pm 0.10V$



# TRAC020LH

## TYPICAL ELECTRICAL CHARACTERISTICS Cell DC Transfer Characteristics

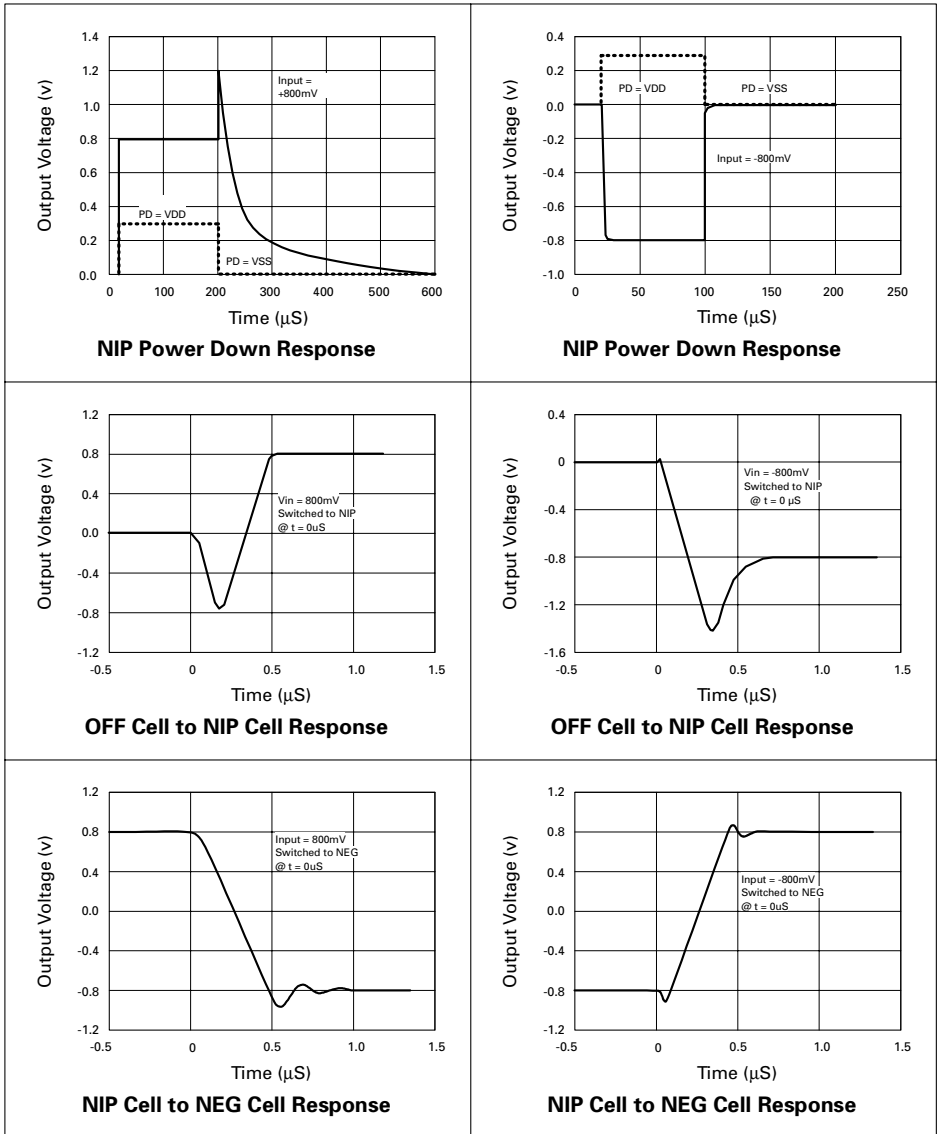
Test Conditions: Temperature = 25 °C,  $V_{DD} = 3.0V \pm 0.15V$ ,  $V_{SS} = -2.0V \pm 0.10V$



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## TYPICAL ELECTRICAL CHARACTERISTICS Settling Performance for Power Down and Data Clcking

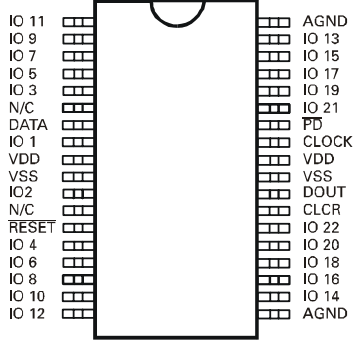
Test Conditions: Temperature = 25 °C,  $V_{DD} = 3.0V \pm 0.15V$ ,  $V_{SS} = -2.0V \pm 0.10V$



# TRAC020LH

## CONNECTION DIAGRAM

QSOP 36 Lead



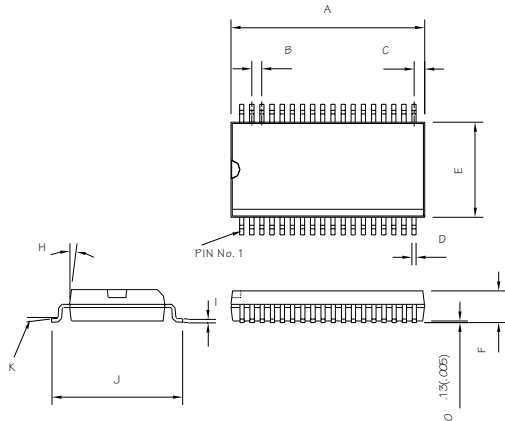
Note:  
For clarity the IO pin definition has been changed from previous issue

TOP VIEW

(NOT TO SCALE)

## PACKAGING INFORMATION

SYMBOL	QSOP 36 LEAD			
	MIN		MAX	
	MM	INCHES	MM	INCHES
A	15.20	.598	15.40	.606
B	0.8MM .031 INCHES BSC			
C	0.85MM .033 INCHES REF			
D	0.29	.011	0.39	.015
E	7.4 0	.291	7.60	.299
F	2.44	.096	2.64	.104
H	7 NOMINAL			
I	0.23	.0091	0.32	.0125
J	10.11	.398	10.51	.414
K	0°		8°	



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