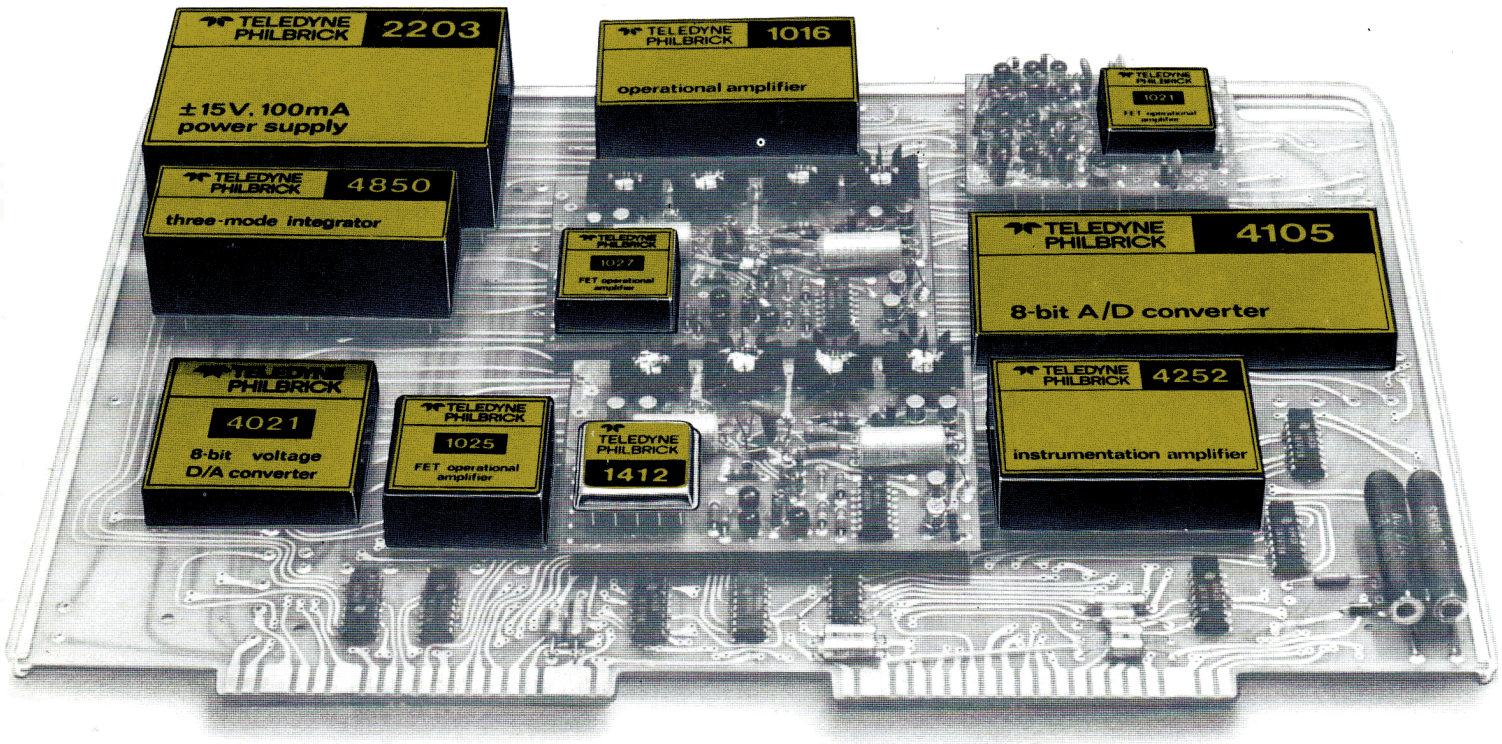
TELEDYNE PHILBRICK

Product Guide 1972



PHILBRICK ≡ CIRCUIT MODULES

LINEAR · NONLINEAR · DATA CONVERSION · POWER · MODULE TESTERS

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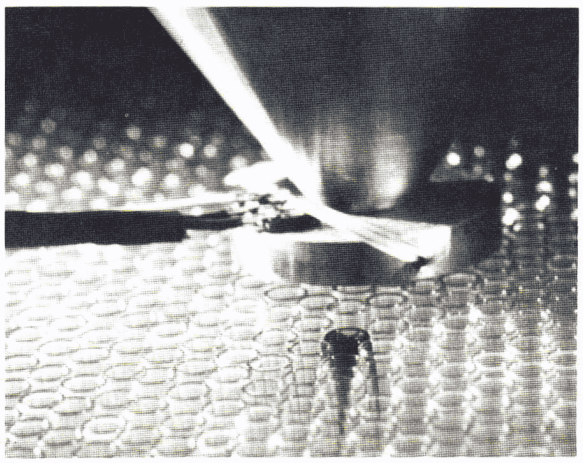
LINEAR • NONLINEAR • DATA CONVERSION • POWER • MODULE TESTERS

In 1946 George A. Philbrick founded a modest new company to explore an emerging technology. . . that of analog computational elements. Among the earliest products of George A. Philbrick Researches, Inc. were a series of operational amplifiers which stirred the imagination of the electronics world and pointed the way to the "packaged circuit module" design concept. From the handful of amplifiers first hand produced by the company has grown an astonishing proliferation of complex and sophisticated circuit modules which encompass a wide variety of analog and digital circuit functions. Now as a division of the Teledyne Corporation, Teledyne Philbrick offers modules for nearly any requirement.

This catalog outlines the standard products presently offered by Teledyne Philbrick and sold through sales offices and distributors throughout the free world. We are confident that you will find at Philbrick the best engineering solution to any design problem which can be solved with packaged circuit modules — either from our standard product line or a custom designed OEM Special.

We appreciate your interest in our company and your continued use of our products.



Precise matching of semiconductor chips to their specific circuit is a critical factor in assuring reliable operation and high performance of hybrid circuit modules that are used in virtually every electronic application from anti-pollution monitors and automotive fuel injection controls to cardiac monitors and lunar seismology. Teledyne Philbrick has recently perfected a unique automated testing system which automatically selects more than 500 semiconductor chips per hour matched to 1000 categories of electrical parameters. An air transport system automatically picks up the chip and deposits it through a delivery tube into a vial which corresponds to its selected electrical parameters.

TABLE OF CONTENTS

NEW PRODUCTS FROM TELEDYNE PHILBRICK

LINEAR

LINEAR MICROCIRCUITS REPLACE 741's

The newest addition to Philbrick's linear product line are the 'optimized 741' micro circuits. Specific performance features include: Model 1339: 34V/μsec slew rate, guaranteed 60 nA max offset current, guaranteed latch-up proof performance; Model 1319: 200,000 open loop gain, 6μV/°C E_{OS}TC; Model 1413: 2 nA typical. 10 nA guaranteed bias current; Model 1420: 10^{11} Ω || 3 pF differential input impedance and −15 pA typical I_B; Model 1321: 100 MHz gain bandwidth, 300MΩ Z_{Diff}, 35V/μsec slew rate; Model 1322: 20 MHz gain bandwidth, 120V/μsec slew rate; Model 1323: 2,000,000 open loop gain, ±80μA quiescent current drain, ±5.5V to ±20V power supply range.

The optimized 741's' are pin-for-pin replacements for the current 741 types. Their improved parameters, however, result from a series of completely new designs. These amplifiers are intended for new applications where the designer would like to use 741 types (for low cost, small size and reliability) but can not use the standard input characteristics, and for upgrading performance of existing circuits presently using 741 amplifiers. See pages 14 and 15 for complete specifications.

TWO HIGH PERFORMANCE FET OP AMPS

Philbrick's two new FET op amps, Models 1026 and 1027, once again demonstrate that discrete component op amps are still here to stay.

The new 1026 (and the selected version 102601) is an economy model featuring open loop gain of 500,000 @ rated load, small signal frequency response of 3MHz; − 20pA initial bias current; low voltage offset drift (50μV/°C for 1026; 20μV/°C for the 102601); and an input impedance of 10^{12}Ω.

The 1027 and 102701 are high speed, fast settling FET amplifiers. Settling time to 0.01% is less than 1μsec. In addition, the 1027 voltage drift is specified at 50μV/°C, while 102701 features drift of 15μV/°C. Both units offer 10MHz unity gain frequency response, and slew rate of 60V/μsec. Output current at ± 10V is a full ± 20mA. See page 7 for 1026 specifications, and page 10 for 1027.

HIGH PERFORMANCE MICROCIRCUIT FET

Model 141410 is a high speed differential FET input op amp in a hermetically sealed, high reliability, microcircuit package. Performance characteristics feature high slewing rate (50V/μsec min), fast settling time (1μsec to 0.01% max), and high output current (± 20mA) in addition to the normal FET input characteristics (Z_{in} 10^{11}Ω, 100pA I_{bias}). The new package is DIP pin-compatible and is ideal for MIL spec designs or stringent commercial applications where high reliability and small size are important. See page 11.

NEW WIDEBAND MICROCIRCUIT

The new low cost microcircuit, Model 1317, is designed for wideband MIL and critical industrial applications. Housed in a hermetically sealed TO-100 package, the 1317 offers an operating temperature range of −55 to +125°C and a small signal gain bandwidth product of 70 MHz. Other features include a 5V/μsec slew rate, and short circuit protection. See page 11.

NEW LOW COST MICROCIRCUIT FET's

Models 140810, 140811 and 140812 are high performance FET input op-amps completely self contained and hermetically sealed in TO-8 microcircuit package. The lowest cost version, 140810, is specified at 75μV/°C voltage drift; −25pA initial bias current, and ± 2.5pA/°C current drift. The highest performance model, 140812, offers −5pA initial bias current ±0.5pA/°C current drift and 25μV/°C voltage/temperature coefficient. The 140811 offers mid performance adequate for most requirements. Specs are 25μV/°C, −10pA, and ± 1 pA/°C. Reliability is extremely good with a calculated MTBF in excess of 1 million hours. See page 7.

INSTRUMENTATION AMPLIFIERS

Two new modular instrumentation amplifiers, Models 4251 and 4252, feature high CMRR of 110 dB, high input impedance of 50 MΩ, low voltage offset of 5μV/°C, and low bias current of 30 nA. These high performance characteristics make these amplifiers well suited to such applications as biomedical probes, strain gages, and pressure transducers. See page 16 for further details.

NONLINEAR

NEW LOG AMPLIFIERS

Model 4356

- Unique Nonlinear Module, $\sinh^{-1}$ Linear Through Zero, Then Three Decades of AC/DC Logging.
- Speech Compression 40dB of Compression
- Wide Bandwidth DC to 10kHz

Philbrick Model 4356 is a new, temperature-compensated, continuous function network with an output voltage proportional to the inverse hyperbolic sine ($\sinh^{-1}$) of the input signal. This ac logarithmic amplifier is useful in applications where a very wide dynamic range signal must be recorded or transmitted. The inverse function can also be generated so that the exact information can be recovered. Model 4356 is also ideally suited for speech communications applications where a nonsaturating amplifier is needed. See page 21.

Model 4361

- 120dB Dynamic Range − 1 nA to 1 mA
- High Accuracy − ±0.5% Referred to input
- Current Ratio Circuit

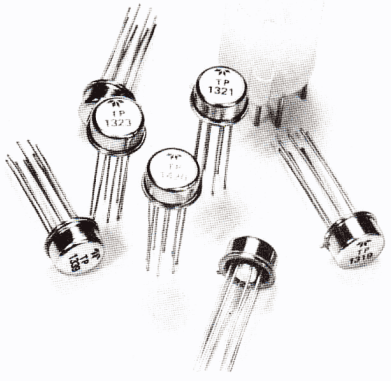
Model 4361 is a logarithmic module designed to give an output voltage proportional to the log ratio of its input currents. The inputs require negative current sources in the range of -10^{-9} to -10^{-3} amperes making it ideally suited for phototube ratio application circuits. This unit is complete with a built-in operational amplifier and precision temperature compensated log ratio element. See page 20.

NEW SQUARE LAW ELEMENTS

Models 4354, 4359, & 4360

- ±0.1% Accuracy
- Low Temperature Coefficient <100 ppm/°C
- Wide Bandwidth, 100 kHz

Models 4353, 4354, 4359 and 4360 are temperature conpensated, straight-line approximation, ten-section diode function fitters that have break points adjusted to fit a square of the input voltage include mean-square and RMS computation, odd-value or ab-squaring or rooting, and "quarter square" multiplication. For complete specifications, see page 23.



DATA CONVERSION

NEW DATA CONVERSION PRODUCT LINE

Teledyne Philbrick now offers a complete line of Digital to Analog and Analog to Digital Converter Modules for display systems, computer interfacing, process control, and test equipment. 8 to 14-bit resolution is combined with an outstanding range of performance characteristics in these self-contained converter modules available from stock. Custom D/A and A/D modules can also be produced, usually within 4 weeks on OEM quantity orders. See pages 26–29 for complete performance specifications.

'Deglitched' D/A Converters

4002 14-Bit Magnitude and Sign Precision
4015 12-Bit High Speed Deglitched DAC
4017 13-Bit High Speed Deglitched DAC
4019 14-Bit High Speed Deglitched DAC

High Performance D/A Modules

4004 12-Bit, Binary Current Output
4005 12-Bit, Binary Voltage Output
4008 12-Bit BCD Current Output
4009 12-Bit BCD Voltage Output
4010 10-Bit Binary Current Output
4011 10-Bit Binary Voltage Output
4012 4-Bit, Expander Module, Current
4013 4-Bit, Expander Module, Voltage
4014 12-Bit, High Speed Current DAC
4016 13-Bit, High Speed Current DAC
4018 14-Bit High Speed Current DAC

Economy D/A Modules

4020 8-Bit, Binary Economy, Current Output
4021 8-Bit, Binary Economy, Voltage Output
4022 10-Bit, Binary Economy, Current Output
4023 10-Bit, Binary Economy, Voltage Output

Analog to Digital Converter Modules

4103 12-Bit, Successive Approximation
4104 10-Bit, Successive Approximation
4105 8-Bit, Successive Approximation
4106 12-Bit, Successive Approximation
4107 10-Bit, Successive Approximation
4108 8-Bit, Successive Approximation
4109 12-Bit, Dual Slope (0 to -10V) Binary
410910 12-Bit, Dual Slope (0 to +10V) Binary
4110 8-Bit, Tracking
4111 12-Bit, Dual Slope (0 to -10V) BCD
411110 12-Bit, Dual Slope (0 to +10V) BCD

POWER

Philbrick has expanded their line of modular power supplies with the addition five ±15V supplies for circuit modules such as op amps, D/A and A/D converters, and nonlinear modules; and two 5 V supplies for logic networks.

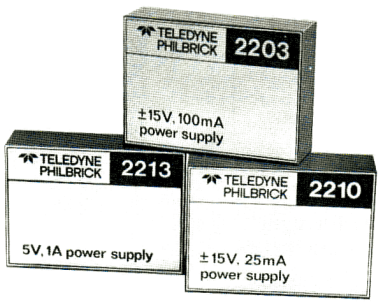
±15 Vdc CIRCUIT MODULE SUPPLIES

Models 2208 and 2209 are high performance, regulated supplies that operate directly from either 115 Vac or 230 Vac, 50 to 400 Hz line. Model 2208 delivers up to ±100 mA and Model 2209 up to ±50 mA, with the output voltage accurate to within ±1% and ±0.03% regulation. Trim pins are provided to vary the output voltage from ±14.5 V to ±15.5 Vdc.

Models 2210, 2211 and 2212 are low cost, dual regulated supplies which deliver up to ±25 mA, ±50 mA, and ±100 mA, respectively. The output voltages are accurate to within ±1% with ±0.1% regulation. The units operate from 115 Vac, 50-400 Hz power or 230 Vac. See page 30.

5 Vdc LOGIC SUPPLIES

Models 2206 and 2213 are single regulated supplies specifically designed to power logic and microcircuits. Output current for Models 2206 and 2213 is 500 mA and 1000 mA, respectively, with regulation 0.1% for both. Model 2206 will operate from either 115 Vac or 230 Vac. Model 2213 operates from 115 Vac. Both supplies offer crowbar protection. See page 31.



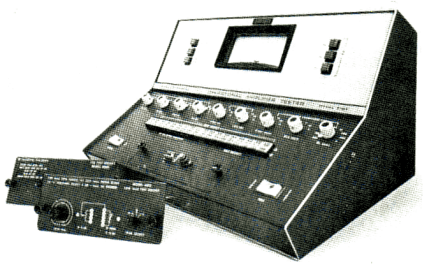
TESTERS

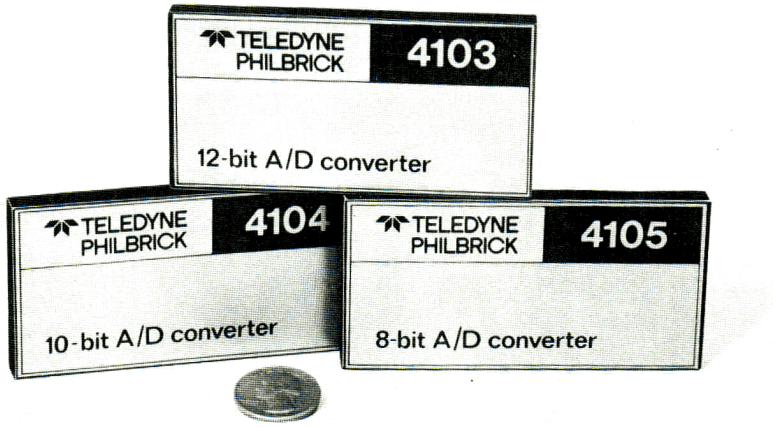
The new Models 5104 and 5107 Automatic Operational Amplifier Tester offers rapid testing of 16 op amp or comparator parameters, including slew rate, in either a fully automatic or semi-automatic mode. In the automatic mode, testing is completed in 3.2 seconds on a GO/NO basis using easily programmable test limits. The semi-automatic mode allows test selection by individual push buttons for a detailed evaluation of amplifier performance.

Non technical personnel are easily trained to use the testers in BOTH the semi-automatic and automatic mode. Test conditions, meter scaling and supply voltages are controlled either by front panel switches or easily accessible internal program cards. Human engineering eliminates areas of possible operator error and provides efficient operation.

Also included on the front panel are push-buttons for verification of power supply voltages and test limits, as well as indicators for GO, NO, and OSCILLATION.

A variety of inexpensive test sockets are available to accommodate most discrete and micro-circuit operational amplifiers, including those with low bias currents. No additional accessories are required for changing between amplifier types. Comparator sockets for testing the Models 710 and 711 in both TO-99 and dual-in-line packages are also available.





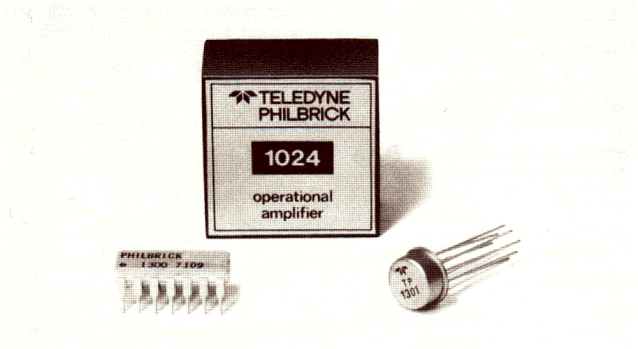
LINEAR MODULES

Operational Amplifier Classification

To aid in the selection of the proper amplifier, we have classified the amplifiers into groups according to general applications requirements. Since there is no universal way to classify amplifiers, the amplifiers have been placed in categories representing their salient specifications and most common applications. The group explanations below list the factors which determine the amplifier classification with cross references for amplifiers that appear in more than one category.

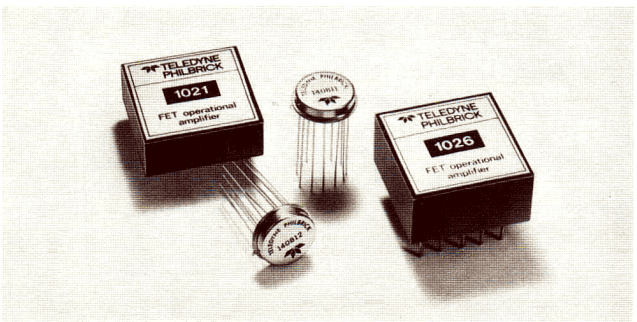
GROUP I – GENERAL PURPOSE – MODERATE PERFORMANCE

Amplifiers in this group are best suited where moderate specifications of voltage drift, current drift, input impedance, external impedance, and bandwidth are acceptable. The voltage drift range will be from 5μV/°C to 30μV/°C and current drift in the range of 0.2 nA/°C to 3 nA/°C. Typical numbers for bandwidth are 1 MHz to 2 MHz and frequency for full output of 10 kHz to 20 kHz. Applications for this group are general, such as inverters, followers as impedance buffers, adders, or amplifiers to be used with non-linear modules.



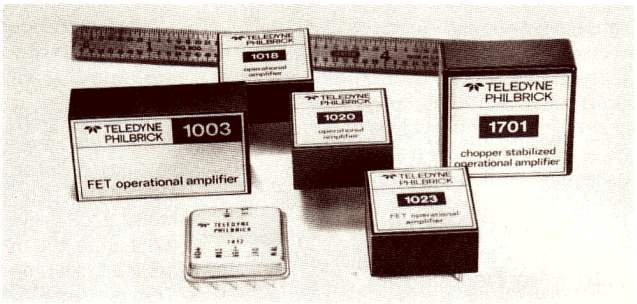
GROUP II – LOW CURRENT ERROR HIGH INPUT IMPEDANCE

FET input amplifiers and parametric (varactor bridge) amplifiers generally appear in this classification. A borderline type is the transistor Darlington input device which has input impedance of about 1 MΩ to 6 MΩ and bias currents of about 1 nA and are better than the general purpose type, but not in the FET and varactor bridge class. The amplifiers in this group are best suited for high impedance levels above 100 kΩ. The high input impedance reduces loading errors due to source resistance and the low leakage currents at the inputs provide for minimum error referred to the output due to factors such as input current multiplied by the feedback resistance causing an error voltage. Applications include integrators, current to voltage converters, sample and hold amplifiers and low level logarithmic amplifiers. The parametric amplifiers (SP2A, SP2AU) will resolve signal levels as low as 10^{-13} amps with source impedance levels up to $10^{12}\ \Omega$. The parametric amplifiers are well suited to measure low frequency, low level signals in such applications as electrometers and seismograph amplifiers.



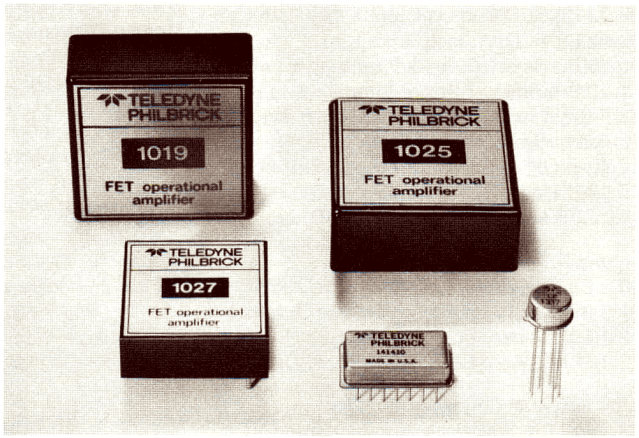
GROUP III – LOW VOLTAGE DRIFT

Amplifiers in this group have the lowest voltage drift due to changes in time, temperature, and power supply variations. The temperature coefficient will be in the range of 0.1μV/°C to 5μV/°C with the lower temperature coefficients appearing in the chopper stabilized amplifiers. Applications for this group are where low level signals are to be resolved or amplified, such as low level signal conditioning and low level comparators.



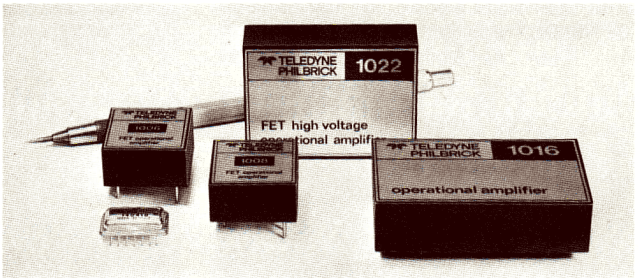
GROUP IV – WIDEBAND, FAST RESPONSE

Important specifications for amplifiers in this class are gain-bandwidth products, frequency for full output, slewing rate, settling time, and overload recovery. Amplifiers in this group will have a unity gain bandwidth of greater than 10 MHz. Applications include high speed A-D and D-A conversion, sample-and-hold circuits, and high speed comparators.



GROUP V – SPECIAL PURPOSE

Special purpose amplifiers include low power drain (micropower, battery operated) wide supply voltage range; high voltage, and high current output types. Refer to individual data sheets for specific applications.



GROUP VI – GENERAL PURPOSE LINEAR MICROCIRCUITS – "OPTIMIZED 741's"

With seven models providing, respectively, high performance and low drift (Model 1319); wideband, high input impedance (1321); high slew rate (1322); micropower general purpose (1323); general purpose economy (1339); low bias current (1413); and general purpose FET input (1420); the "optimized 741's" are pin-for-pin replacements for the current 741 types. Their improved parameters, however, result from a series of completely new designs.

Salient Individual Parameters for Operational Amplifiers

Output Range	E_o	Voltage, min	1022, 1005
	I_o	Current, min	1016, 1017, 1008
Voltage Gain	A_o	Rated load, min	1003, 1700, 1018, 1020, 1701, 170101
Frequency Response (Inverting)	f_t	Small signal (unity gain, open loop), min	1025, 1019, 1317, 1011, 1700, 141410, 1027, 1321
	f_s	Large signal: full output (undistorted), min	1025, 1019, 1011, 1414, 1016, 1700, 1026, 1027
	f_p	full output (peak-to-peak), min	1025, 1010, 1011, 1414, 1016, 1700, 1026, 1027
	s_r	Slew rate	1025, 1019, 1011, 1414, 1016, 1700, 1026, 1027, 1322
	t_s	Settling time	1025, 1019, 1011, 1414, 1016, 1700, 1026, 1027
Input Voltage Range	E_{CM}	Common mode (dc linear operation), min	1022, SP2A, 1003, 1005, 1402, 1016
	E_D	Differential (between inputs), abs max	1022, 1003, 1005, 1016, 1402
	CMRR	Common mode rejection ratio (dc)	SP2A, 1003, 1023, 1021, 1018, 1020, 1022, 1016
Input Voltage Offset	E_{os}	Initial (without external trim) @ 25°C	1701, 1412, 1003, 1700, 1023, USL-1, 1020, 1018, 140810, 140201, 170101
	$E_{os}TC$	Vs. Temperature (avg. −25 to +85°C), max	170002, 1701, 1412, 101802, 102003, 102301, 1003, 170101
	$\Delta E_{os}/\Delta t$	Vs. Time (per day)	1701, 1412, 1700, USL-1, 1018, 1020, 170101
	PSRR	Vs. Power supply	1701, 1412, 1700, USL-1, 1003, 1022, 1016, 170101
Input Bias Current	I_B	Initial @ 25°C, max	SP2A, 100301, 140812, 1021, 101102
	I_BTC	Vs. Temperature (avg. -25 to +85°C), max	SP2A, 1700, 100301, 140812, 1023, 1006, 1402
	$\Delta I_B/\Delta V_{CC}$	Vs. Power Supply	SP2A, 1701, 1700, 1003, 1022, 1402, 1408, 1009, 1011, 1026, 170101
	$\Delta I_B/\Delta t$	Vs. Time (per day)	SP2A, 1701, 1412, 1700, 1402, 1009, 140810, 170101
	I_D	Difference (tracking)	SP2A, 1003, 140812, 1023, 1021, 1006, 1009
Input Impedance	Z_D	Differential	SP2A, 1021, 1023, 1402, 1009, 1420
	Z_{CM}	Common mode (either input to common)	SP2A, 1021, 1023, 1003, 1402, 1009, 1420
Noise (Referred to input)	e_n	Flicker Voltage p-p	SP2A, 1701, 1700, 1023, 1021, 1018, 1020, 170101, 1319
	i_n	(0.016 to 1.6 Hz) Current p-p	SP2A, 1003, 1402, 1006, 1408, 1023, 1021
	e_n	Midband Voltage rms	SP2A, 1700, 1017, 1300, 140410
	i_n	(1.6 to 160 Hz) Current rms	SP2A, 1003, 1006, 1009, 140810
	e_n	Broadband Voltage rms	1300, 1301, 1303, 1016, 1017, 1005
	i_n	(160 Hz to 16 kHz) Current rms	1003, 1402, 1011, 1022, 1026
Power Requirements	$\pm V_{CC}$	Voltage range	1022, Q-200, 1006, 1402, 140410
	I_{CC}	Current: quiescent, max	Q-200, 1006, 1402, 140410
Temperature Range (°C)	T_o	Operating	1300, 1301, 1303, 1317
	T_s	Storage	1300, 1301, 1303, 1317, 1319, 1321, 1322, 1323, 1339
Price		Low Cost High Value	1300, 1301, 1303, 1413, 1024, 1317, 1319, 1339

Operational Amplifier Classification Cross Reference

GENERAL PURPOSE	FET INPUT LOW CURRENT ERROR HIGH INPUT IMPEDANCE	LOW VOLTAGE DRIFT	FAST RESPONSE WIDEBAND	SPECIAL PURPOSE HIGH VOLTAGE, HIGH CURRENT, LOW POWER DRAIN	GENERAL PURPOSE LINEAR MICROCIRCUITS
GROUP I	GROUP II	GROUP III	GROUP IV	GROUP V	GROUP VI
SQ-10A 1024 1300 1301 1303 1339	QFT-2 1009 1025 QFT-2A 100901 1026 QFT-2B 100902 1402 QFT-5 1011 140201 SP2A 101101 140810 SP2AU 101102 140811 1003 1019 140812 100301 1021 140810 1006 1023 1414 1008 102301 141410 1022 1420	QFT-2B 101802 102301 1003 101803 1412 100301 101804 1700 1018 1020 170001 101801 102001 170002 102002 170021 102003 170022 1023 170023 1319 1701 170101 170121	1011 141410 101101 1700 101102 170001 1016 170002 1019 170021 1025 170022 1027 170023 1317 1321 1322 1407	Q-200 1402 1005 140201 1006 140410 1008 140411 1016 1017 1022 1323	1319 1321 1322 1323 1339 1413 1420

Group I General Purpose

Specifications typical at 25°C with nominal power supply, unless otherwise indicated.

				DISCRETE		MICROCIRCUIT		
				SQ-10a General Purpose	1024 Economy 20 mA	1300 Dual Amplifier 1301 1303 709 Pin Configuration		
Output Range	E_o	Voltage, min		±10 V	±10 V	±10 V		
	I_o	Current, min		±5 mA	±20 mA	±2.0 mA		
Voltage Gain (dc open loop)	A_o	Rated load, min		25,000	50,000	10,000		
		10 k load, min		60,000	– –	– –		
Frequency Response (Inverting)	f_t	Small signal (unity gain, open loop), min		1 MHz	2 MHz(typ.)	1 MHz [1]		
	f_s	Large signal: full output (undistorted) min		14 kHz	100 kHz	10 kHz [1]		
	f_p	full output (peak-to-peak), min		20 kHz	250 kHz typ.	– –		
	S_r	Slew rate		1.4 V/μSec	9 V/μSec	0.6 V/μSec [1]		
	t_s	Settling time (0.1%)		– –	5 μSec	– –		
Input Voltage Range	E_{CM}	Common mode (dc linear operation), min		±10 V	±10 V	±11 V		
		(fault), abs max		±16 V	±15 V	±15 V		
	E_D	Differential (between inputs), abs max		32 V	5 V	30 V		
	CMRR	Common mode rejection ratio (dc)		20,000	20,000	4000 (min)		
Input Voltage Offset	E_{os}	Initial (without external trim) @ 25°C		– –	±10 mV	±10 mV (max)		
	R_{os}	Zero adjustment		50 kΩrhst.	10 kΩrhst.	(see data sheet)		
	$E_{os}TC$	Vs. Temperature (avg. –25 to + 85°C), max		±20 μV/°C	±20 μV/°C	±40 μV/°C (@25°C) [2]		
	$\Delta E_{os}/\Delta t$	Vs. Time (per day)		±100 μV	±50 μV	±50 μV		
	PSRR	Vs. Power Supply		±200 μV/V	±100 μV/V	±30 μV/V		
Input Bias Current	I_B	Initial @ 25°C, max		±100 nA	±50 nA	+1 μA		
	I_BTC	Vs. Temperature (avg. –25 to + 85°C), max		±2 nA/°C	±0.6 nA/°C	±8 nA/°C (@25°C) [3]		
	$\Delta I_B/\Delta V_{CC}$	Vs. Power Supply		±6 nA/V	±1 nA/V	±20 nA/V		
	$\Delta I_B/\Delta t$	Vs. Time (per day)		±3 nA	±0.5 nA	±10 nA		
	I_D	Difference (tracking)		±16 nA	±25 nA	±30 nA		
Input Impedance	Z_D	Differential		300 kΩ||8pF	1 MΩ||6pF	210 kΩ||30pF		
	Z_{CM}	Common mode (either input to common)		30 MΩ||8pF	50 MΩ||6pF	200 MΩ||3pF		
Noise (Referred to input)	e_n	Flicker (0.016 to 1.6 Hz)	Voltage p-p	8 μV	7 μV	4 μV		
	i_n		Current p-p	170 pA	34 pA	250 pA		
	e_n	Midband (1.6 to 160 Hz)	Voltage rms	1.2 μV	2 μV	1.5 μV		
	i_n		Current rms	100 pA	22 pA	60 pA		
	e_n	Broadband (160 Hz to 16 kHz)	Voltage rms	0.9 μV	2 μV	1 μV		
	i_n		Current rms	100 pA	7 pA	80 pA		
Power Requirements	$\pm V_{CC}$	Nominal Supply Voltage		±15 V	±15 V	±15 V		
		Voltage range		±8 to ± 16 V	±12 to ± 18 V	±3 to ± 16 V		
	I_{CC}	Current: quiescent, max		±10 mA	±9 mA	±6 mA		
		full load, max		–10, + 15 mA	±29 mA	±8 mA		
Temperature Range (°C)	T_o	Operating		-25 to + 85	-25 to + 85	-25 to +100		
	T_s	Storage		-55 to +100	-55 to +125	-62 to +150		
Mechanical See pages 38-43		Outline drawing		A1	A1	TO-116	TO-99	TO-116
		Socket		NSK-20 ($1.60)	NSK-20 ($1.60)	See Note 4		
Price		Quantity (1–9)		$11.00	$19.00	$6.00	3.50	3.50
		(10–24)		$10.50	$18.00	$5.80	3.40	3.40

NOTES

1. Use damping scheme IV, (see 1300 data sheet)
2. ΔE_{os} ±5 mV, max (–25 to +100°C)
3. ΔI_{bias} ±2 μA, max (–25 to +100°C)
4. Sockets for the TO-99 and TO-116 packages are not supplied by Teledyne Philbrick, available from Barnes Corp., Lansdowne, Pa.

Group II Low Current Drift High Input Impedance

	DISCRETE				FET-MICROCIRCUIT	
	1026 102601 FET, General Purpose	1009 100901 100902 FET, General Purpose	1021 FET High CMRR Economy	SP2A SP2AU Parametric Premium	1408 140801 140802 FET, Economy	140810 140811 140812 FET, Economy
	±10 V	±10 V	±10 V	±10 V	±10 V	±10 V
	±5 mA	±5 mA	±20 mA	±2.2 mA	±5 mA	±5 mA
	500,000	50,000	100,000	20,000	250,000	250,000
	– –	80,000	– –	40,000	500,000	500,000
	4 MHz (typ.)	1 MHz	2 MHz	75 kHz	1 MHz (typ)	1 MHz (typ)
	– –	50 kHz	100 kHz	1.1 kHz	50 kHz	50 kHz
	100 kHz	– –	150 kHz typ.	– –	– –	– –
	6V/µSec	5 V/µSec	6 V/µSec	0.08 V/µSec	3 V/µSec	3 V/µSec
	10 µsec	– –	10 µs	– –	– –	– –
	±10 V	+7, -10 V	±10 V	±300 V	±10 V	±10 V
	±15 V	±15 V	±18 V	±330 V	±15 V	±15 V
	30 V	30 V	36 V	30 V	30 V	30 V
	10,000 (min)	1,000	1,000,000	10^{10} (@±300 V)	10,000	10,000
	– –	– –	– –	– –	±2 | 1 | 1 mV	±2 | 1 | 1 mV
	1 kΩrhst.	1 kΩrhst.	2 kΩrhst.	Built-in	internal trim	internal trim
	±50 | 20 µV/°C	±75 | 50 | 25 µV/°C	±50 µV/°C	±90 | 160 µV/°C [2]	±75 | 25 | 25 µV/°C	±75 | 25 | 25 µV/°C
	±50 µV	±50 µV	±100 µV	±100 µV	±50 µV	±50 µV
	±300 µV/V	±300 µV/V	±300 µV/V	±1 mV/V	±350 µV/V	±350 µV/V
	-50 | -20 pA	-30 | 20 | 20 pA	-10 pA	±1 pA | ±10 pA	-25 | -10 | -5 pA	-25 | -10 | -5pA
	doubles|10°C	doubles|10°C	±1 pA/°C [1]	±0.16 | 1.6 pA/°C	±2.5 | 1 | 0.5 pA/°C [1]	±2.5 | 1 | 0.5 pA/°C [1]
	±5 pA/V	±5 pA/V	±5 pA/V	– –	±3 pA/V	±3 pA/V
	±1 pA	±1 pA		±0.1 pA	±1 pA	±1 pA
	±10 pA	±10 pA	±3 pA		±10 | 5 | 2 pA	±10 | 5 | 2 pA
	10^{11} Ω||5pF	10^{11} Ω||5pF	10^{11} Ω||10pF	10^{10} Ω||500pF	10^{11} Ω||4pF	10^{11} Ω||4pF
	10^{11} Ω||5pF	10^{11} Ω||5pF	10^{12} Ω||10pF	10^{12} Ω||5pF	10^{11} Ω||4pF	10^{11} Ω||4pF
	5 µV	5 µV	1.5 µV	1 µV	6 µV	6 µV
	0.2 pA	0.2 pA	0.1 pA	1 fA	0.2 pA	0.2 pA
	2.2 µV	2.2 µV	4 µV	1 µV	2 µV	2 µV
	1 pA	1 pA	– –	0.5 pA	1 pA	1 pA
	2.2 µV	2.2 µV	4 µV	10 µV	2 µV	2 µV
	2 pA	2 pA	– –	500 pA	3 pA	3 pA
	±15 V	±15 V	±15 V	±15 V	±15 V	±15 V
	±10 to ±18 V	±10 to ±18 V	±12 to ±18 V	±12 to ±18 V	±10 V to ±22 V	±10 V to ±22 V
	±12 mA	±12 mA	±5 mA	+9, -7 mA	±5 mA	±5 mA
	±17 mA	±17 mA	±25 mA	±9.2 mA	±10 mA	±10 mA
	-25 to +85	-25 to +85	-25 to +85	0 to +65	-25 to +85	-25 to +85
	-55 to +125	-55 to +125	-55 to +125	-55 to +85	-55 to +125	-55 to +125
	A1	A1	A1	SP	T1	TO-8
	NSK-20 ($1.60)	NSK-20 ($1.60)	NSK-20 ($1.60)	MB-SP (Supplied)	6035 ($2.50)	US-Q ($3.50)
	$12.00 | 18.00	$11.50 | 24.00 | 31.00	$33.00	$185.00 | 160.00	$25.00 | 33.00 | 43.00	$25.00 | 33.00 | 43.00
	$11.75 | 17.25	$11.25 | 22.90 | 29.75	$31.50	$153.00 | 134.00	$24.50 | 31.50 | 41.50	$24.50 | 31.50 | 41.50

NOTES

1. Slope at +25°C, doubles each +10°C
2. 0 to +65°C

Specifications listed left to right correspond to model numbers top to bottom above.

Selected versions are available on all models, consult factory.

Group III Low Voltage Drift

DISCRETE

DIFFERENTIAL

Specifications typical at 25°C with nominal power supply, unless otherwise indicated.

			1020 102001 102002 102003 Economy, Low Drift Differential	1018 101801 101802 101803 101804 Low Drift, Differential	1023 102301 FET Low Drift
Output Range	E_o	Voltage, min	±10 V	±10 V	±10 V
	I_o	Current, min	±5 mA	±2.5 mA	±20 mA
Voltage Gain (dc open loop)	A_o	Rated load, min	3 x 10^5	10^6	100,000
		10 k load, min	10^6	10^6	– –
Frequency Response (Inverting)	f_t	Small signal (unity gain, open loop), min	0.5 MHz	0.5 MHz	2 MHz
	f_s	Large signal: full output (undistorted) min	– –	5 kHz (typ)	100 kHz
	f_p	full output (peak-to-peak), min	10 kHz	7 kHz (typ)	150 kHz (typ)
	s_r	Slew rate	0.3 V/μSec	0.3 V/μSec	6 V/μSec (min)
	t_s	Settling time (0.1%)	– –	– –	10 μSec
Input Voltage Range	E_{CM}	Common mode (dc linear operation), min	±10 V	±10 V	±10 V
		(fault), abs max	±15 V	±18 V	±18 V
	E_D	Differential (between inputs), abs max	30 V	36 V	36 V
	CMRR	Common mode rejection ratio (dc)	100,000	100,000	1,000,000
Input Voltage Offset	E_{os}	Initial (without external trim) @ 25°C	±3 | 0.5 | 0.5 | 0.5 mV[1]	±1.0 | 0.1 | 0.1 | 0.25 | 0.1 mV[1]	±700 μV (max)[2]
	R_{os}	Zero adjustment	– –	– –	– –
	$E_{os}TC$	Vs. Temperature (avg. -25 to +85°C), max	±5 | 1.5 | 0.5 | 0.25 μV/°C[1]	±1.5 | 0.5 | 0.25 | 1.5* | 0.5μV/°C*[1]	±5 | 2μV/°C[3]
	$\Delta E_{os}/\Delta t$	Vs. Time (per day)	±5 μV	±5 μV	±20 μV
	PSRR	Vs. Power Supply	±50 μV/V	±25 μV/V	±100 μV/V
Input Bias Current	I_B	Initial @ 25°C, max	±25 nA	±2 nA	-10 pA
	I_BTC	Vs. Temperature (avg. -25 to +85°C), max	±500 pA/°C	±100 | 50 | 50 | 100* | 50*	±1 pA/°C[4]
	$\Delta I_B/\Delta V_{CC}$	Vs. Power Supply	±0.7 nA/V	±0.4 nA/V	±5 pA/V
	$\Delta I_B/\Delta t$	Vs. Time (per day)	– –	– –	– –
	I_D	Difference (tracking)	±5 nA (max)	±0.4 nA	±3 pA
Input Impedance	Z_D	Differential	4 MΩ||8pF	4 MΩ||8pF	10^{11} Ω||10pF
	Z_{CM}	Common mode (either input to common)	1000 MΩ||8pF	1000 MΩ||8pF	10^{12} Ω||10pF
Noise (Referred to input)	e_n	Flicker (0.016 to 1.6 Hz) Voltage p-p	2 μV	2 μV	1.5 μV
	i_n	Current p-p	50 pA	50 pA	0.1 pA
	e_n	Midband (1.6 to 160 Hz) Voltage rms	3 μV	3 μV	4 μV
	i_n	Current rms	6 pA	6 pA	– –
	e_n	Broadband (160 Hz to 16 kHz) Voltage rms	3 μV	3 μV	4 μV
	i_n	Current rms	6 pA	6 pA	– –
Power Requirements	$\pm V_{CC}$	Nominal Supply Voltage	±15 V	±15 V	±15 V
		Voltage range	±12 to ±18 V	±12 to ±18 V	±12 to ±18 V
	I_{CC}	Current: quiescent, max	±12 mA	±6 mA	±6 mA
		full load, max	+17,-12 mA	±8.5 mA	±26 mA
Temperature Range (°C)	T_o	Operating	-25 to +85	-25 to +85	-10 to +60
	T_s	Storage	-55 to +125	-55 to +125	-55 to +125
Mechanical See pages 38-43		Outline drawing	A1	A1	A1
		Socket	NSK-20($1.60)	NSK-20($1.60)	NSK-20($1.60)
Price		Quantity (1–9)	$27.00 | 39. | 55.00 | 65.	$74.00 | 98.00 | 110. | 68. | 88.	$59.00 | 69.00
		(10-24)	$26.00 | 37. | 52.50 | 62.	$70.50 | 93.50 | 105. | 65. | 84.	$56.50 | 66.00

NOTES

1. With external trim resistor supplied *+10 to +60°C
2. With supplied metal film resistor
3. -10 to +60°C
4. Slope at +25°C, doubles each +10°C
5. 1,000,000 minimum
6. Maximum +10 to +60°C
7. ±1 pA/°C, max (0 to +60°C)

DISCRETE | MICROCIRCUIT

CHOPPER STABILIZED

	1003 100301 FET High CMRR	1700 170001 170002 High Gain Encapsulated	170021 170022 170023 High Gain, Plug-in	1701 170101 Economy Encapsulated	170121 170122 Economy Plug-in	1412 'Mini' Chopper Stabilized Microcircuit
	±|Vcc-5|V	±10 V	±10 V	±12 V	±12 V	±12 V
	±20 mA	±20 mA	±20 mA	±5 mA	±5 mA	±5 mA
	1,000,000	10^8	10^8	10^7	10^7	10^6
	500,000	4×10^8	4×10^8	– –	– –	– –
	1.5 MHz	16 MHz	16 MHz	1 MHz (typ)	1 MHz (typ)	1 MHz (typ)
	– –	1 MHz	1 MHz	20 kHz	20 kHz	20 kHz
	100 kHz	1.2 MHz	1.2 MHz	– –	– –	– –
	7 V/μSec	200 V/μsec	200 V/μsec	1.2 V/μSec min.	1.2 V/μSec min.	1.2 V/μSec min
	10 μSec	4 μSec (max)	4 μSec (max)	– –	– –	– –
	±|Vcc-7|V	– –	– –	– –	– –	– –
	±Vcc	– –	– –	– –	– –	– –
	56 V	15 V	15 V	30 V	30 V	30 V
	3,000,000 [5]	– –	– –	– –	– –	– –
	±300 μV (max)	±45 μV (max)	– –	±15 μV(max)	– –	±25 μV(max)
	1 kΩpot	1 MΩpot	Supplied int.	50 kΩpot	Supplied int.	50 kΩpot
	±4 | 2 μV/°C [6]	±1 | 0.5 | 0.2 μV/°C	±1 | 0.5 | 0.2 μV/°C	±0.25 | 0.1 μV/°C	±0.25 | 0.1 μV/°C	±0.5 μV/°C
	±10 μV	±1 μV	±1 μV	±5 μV/yr	±5 μV/yr	±1 μV/mo
	±3 μV/V	±10 μV/V	±10 μV/V	±0.2 μV/V	±0.2 μV/V	±0.25 μV/V
	-10 | -5 pA	±95 pA	±95 pA	±50 pA	±50 pA	±100 pA
	±1 | 0.5 pA/°C [4]	±2 pA/°C [7]	±2 pA/°C [7]	±1 pA/°C	±1 pA/°C	±5 pA/°C
	±0.5 pA/V	±20 pA/V	±20 pA/V	±2 pA/V	±2 pA/V	±3 pA/V
	– –	±2 pA	±2 pA	±10 pA/yr	±10 pA/yr	±1 pA/mo
	±5 pA	– –	– –	– –	– –	– –
	10^{11} Ω||5pF	500 kΩ||66pF	500 kΩ ||66pF	500 kΩ||100pF	500 kΩ||100pF	500 kΩ ||100pF
	10^{12} Ω||5pF	– –	– –	– –	– –	– –
	4 μV	3 μV	3 μV	1 μV	1 μV	5 μV
	0.1 pA	6 pA	6 pA	5 pA	5 pA	– –
	2 μV	1 μV	1 μV	2 μV	2 μV	5 μV
	0.7 pA	20 pA	20 pA	– –	– –	– –
	2 μV	2.3 μV	2.3 μV	5 μV	5 μV	7 μV
	1 pA	350 pA	350 pA	– –	– –	– –
	±15 V	±15 V	±15 V	±15 V	±15 V	±15 V
	±8 to ±28 V	±12 to ±18 V	±12 to ±18 V	±8 to ±20 V	±8 to ±20 V	±8 to ±20 V
	±4.5 mA	±12 mA	±12 mA	±3 mA	±3 mA	±3 mA
	±26 mA	±31 mA	±31 mA	±8 mA	±8 mA	±8 mA
	-25 to +85	-25 to +85	-25 to +85	-25 to +85	-25 to +85	-25 to +85
	-65 to +155	-55 to +100	-55 to +100	-55 to +125	-55 to +125	-55 to +125
	E1	E4	SP	E5	SP	A5
	NSK-14 ($1.70)	6023 ($5.00)	Supplied	NSK-20($1.60)	Supplied	6053 ($4.00)
	$95.00 | 115.00	$98.00 | 108.00 | 115.00	$125.00 | 135.00 | 145.00	$58.00 | 75.00	$130.00 | 145.00	$125.00
	$90.00 | 110.00	$93.50 | 103.00 | 110.00	$120.00 | 130.00 | 139.00	$56.00 | 71.50	$124.00 | 139.00	$120.00

Specifications listed left to right correspond to model numbers top to bottom above.

Selected versions are available on all models, consult factory.

Group IV Wideband Fast Response

DISCRETE

Specifications typical at 25°C with nominal power supply, unless otherwise indicated.

				1011 101101 101102 Fast FET, Differential	1027 102701 Fast FET, Differential	1019 High Slew Rate FET, Differantial
Output Range	E_o	Voltage, min		±10 V	±10 V	±10 V
	I_o	Current, min		±20 mA	±20 mA	±20 mA
Voltage Gain (dc open loop)	A_o	Rated load, min		100,000	100,000	100,000
		10 k load, min		500,000 (typ)	– –	– –
Frequency Response (Inverting)	f_t	Small signal (unity gain, open loop), min		12 MHz	10 MHz	100 MHz
	f_s	Large signal: full output (undistorted) min		1 MHz [1]	500 kHz	5 MHz
	f_p	full output (peak-to-peak), min		– –	1 MHz	10 MHz
	s_r	Slew rate		70 V/μSec	60 V/μSec [2]	1000 V/μSec
	t_s	Settling time (0.01%)		3 μSec [2]	1 μSec	500 nSec (max)
Input Voltage Range	E_{CM}	Common mode (dc linear operation), min		±10 V	±10 V	±10 V
		(fault), abs max		±18 V	±15 V	±18 V
	E_D	Differential (between inputs), abs max		36 V	30 V	36 V
	CMRR	Common mode rejection ratio (dc)		2,000	10,000	100,000 (min)
Input Voltage Offset	E_{os}	Initial (without external trim) @ 25°C		– –	±15 mV	±2 mV (max)
	R_{os}	Zero adjustment		1 kΩrhst	1 kΩrhst	100 kΩpot
	$E_{os}TC$	Vs. Temperature (avg. -25 to +85°C), max		±50 | 25 | 10 μV/°C	±50 | 15 μV/°C	±25 μV/°C
	$\Delta E_{os}/\Delta t$	Vs. Time (per day)		±50 μV	±50 μV	±100 μV
	PSRR	Vs. Power Supply		±70 μV/V	±300 μV/V	±200 μV/V
Input Bias Current	I_B	Initial @ 25°C, max		-30 | -20 | -20 pA	-50 pA	-50 pA
	I_BTC	Vs. Temperature (avg. -25 to +85°C), max		doubles/+10° C	doubles/+10° C	doubles ea. +10°C
	$\Delta I_B/\Delta V_{CC}$	Vs. Power Supply		±1 pA/V	±1 pA/V	±1 pA/V
	$\Delta I_B/\Delta t$	Vs. Time (per day)		– –	– –	±2 pA
	I_D	Difference (tracking)		±10 pA (max)	±10 pA (max)	±10 pA
Input Impedance	Z_D	Differential		$10^{12}\Omega\|\|4pF$	$10^{11}\Omega\|\|5pF$	$10^{11}\Omega\|\|5pF$
	Z_{CM}	Common mode (either input to common)		$10^{12}\Omega\|\|4pF$	$10^{11}\Omega\|\|5pF$	$10^{12}\Omega\|\|25pF$ [3]
Noise (Referred to input)	e_n	Flicker (0.016 to 1.6 Hz)	Voltage p-p	5 μV	5 μV	15 μV
	i_n		Current p-p	0.2 pA	0.5 pA	0.1 pA
	e_n	Midband (1.6 to 160 Hz)	Voltage rms	2.2 μV	2 μV	0.5 μV
	i_n		Current rms	1 pA	– –	– –
	e_n	Broadband (160 Hz to 16 kHz)	Voltage rms	2.2 μV	4 μV	3 μV
	i_n		Current rms	1 pA	– –	– –
Power Requirements	$\pm V_{CC}$	Nominal Supply Voltage		±15 V	±15 V	±15 V
		Voltage range		±12 to ±18 V	±12 to ±18 V	±12 V to ±18 V
	I_{CC}	Current: quiescent, max		±13 mA	±12 mA	±50 mA
		full load, max		±30 mA	±30 mA	±65 mA
Temperature Range (°C)	T_o	Operating		-25 to +85	-25 to +85	-25 to +85
	T_s	Storage		-55 to +125	-55 to +125	-55 to +125
Mechanical See pages 38-43		Outline drawing		A4	A4	E5
		Socket		NSK-20($1.60)	NSK-20($1.60)	NSK-20($1.60)
Price		Quantity (1-9)		$42.00 | 55.00 | 60.00	$35.00 | 45.00	$125.00
		(10-24)		$41.50 | 54.00 | 59.00	$33.50 | 43.00	$120.00

NOTES

1. 800 kHz noninverting
2. Guaranteed Maximum
3. 5 pF negative input to common
4. 75 nsec to 0.1% max
5. This socket not supplied by Teledyne Philbrick, available from Barnes Corp., Lansdowne, Pa.
6. At gain of 1000 (see 1317 data sheet)

MICROCIRCUIT

	1025 Fast Settling FET	141410 Hermetically Sealed Fast Differential FET	1317 Wideband Monolithic
	±10 V	±10 V	±10 V
	±50 mA	±20 mA	±10 mA
	100,000	100,000	20,000
	– –	200,000	20,000
	50 MHz	10 MHz (typ)	70 MHz [6]
	5 MHz	500 kHz	90 kHz [6]
	10 MHz (typ)	1 MHz (typ)	– –
	500 V/μSec (min)	50 V/μSec (min)	5 V/μSec [6]
	300 nSec (max) [4]	1 μSec (max)	– –
	±2 V	±10 V	±7 V
	±18 V	±18 V	±15 V
	36 V	36 V	20 V
	10,000 (Typ)	5,000 (typ)	10,000
	±10 mV (max)	±5 mV	±10 mV
	1 kΩrhst	1 kΩpot	250 kΩpot
	±50μV/°C	±50 μV/°C	±18 μV/°C
	±50 μV	± 100 μV	±50 μV
	±200 μV/V	±500 μV/V	±100 μV/V
	-50 pA	-100 pA	+750 nA
	doubles ea. +10°C	doubles ea. +10°C	±9 nA/°C
	±1 pA/V	±5 pA/V	– –
	±2 pA	±2 pA	±10 nA
	±10 pA	±10 pA	±50 nA
	10^{11} Ω||8pF	10^{11} Ω||3pF	1 MΩ||3pF
	– –	10^{11} Ω||3pF	500 MΩ||10pF
	15 μV	15 μV	8 μV
	0.1 pA	0.1 pA	200 pA
	0.5 μV	4 μV	2 μV
	– –	– –	40 pA
	3 μV	4 μV	1.5 μV
	– –	– –	80 pA
	±15 V	±15 V	±15 V
	±12 V to ±18 V	±10 to ±18 V	±12 to ±16 V
	±40 mA	±10 mA	±8 mA
	±85 mA	±32 mA	±17 mA
	-25 to +85	-25 to +85	-55 to +125
	-55 to +125	-55 to +125	–62 to +150
	E5	S4	TO-100
	NSK-20($1.60)	See Note 5	See Note 5
	$75.00	$63.00	$14.00
	$71.50	$52.50	$11.50

Specifications listed left to right correspond to model numbers top to bottom above.

Selected versions are available on all models, consult factory.

The concern with settling time is fairly new. Until quite recently, almost everyone, manufacturer and user alike, was quite content to characterize the speed performance of an operational amplifier with such comfortable and well-understood parameters as large-signal and small-signal bandwidth, slewing rate, and (occasionally) overload recovery times. The virtual explosion in the use of D/A and A/D converters (among other things) has brought into sharp focus the fact that for many, if not most, high-speed applications, these specifications are just not adequate to predict the ultimate performance of high-speed circuitry. A reasonable definition of settling time is this:

Settling time is the total time elapsed from the time of input of a non-saturating input step to the time at which the amplifier's output has entered and finally settled within a prescribed error band centered around the final DC value.

The reason that settling time cannot be predicted from bandwidth and/or slewing rate is that when a step input is applied to the amplifier, the output will slew at its maximum rate toward the final value. Usually, however, the output will overshoot slightly, then " ring" as it settles toward the final value. Settling time includes not only the slewing time but the ringing time as well until the peak of the ringing is within the error band of interest. The error band is generally expressed as a percentage of the output step amplitude (for example, 0.1% or 0.01%) and for testing purposes, the output is generally a full scale step. That is, from zero to + 10 volts, zero to −10 V (in the case of a 10 V amplifier) or from ±10 V to zero.

It should also be realized that knowing the settling time to a given accuracy (say 0.1%) is in no way helpful in extrapolating the settling time to a higher accuracy such as 0.01%.

For an exhaustive treatment on the measurement of settling time entitled "The Subtleties of Settling Time," we refer you to *The New Lightning Empiricist,* April 1971. Your free copy is available from Teledyne Philbrick by simply completing and mailing the post-paid card at the rear of the catalog.

Group V Special Purpose

DISCRETE

HIGH VOLTAGE

Specifications typical at 25°C with nominal power supply, unless otherwise indicated.

				1005 High Voltage	1022 High Voltage FET	1008 FET, High Current
Output Range	E_o	Voltage min		±20 V	±|V_{CC} −10|V	±10 V
	I_o	Current, min		±5 mA	±20 mA	±30 mA
Voltage Gain (dc open loop)	A_o	Rated load, min		50,000	1,000,000	50,000
		10 k load, min		250,000	– –	250,000
Frequency Response (Inverting)	f_t	Small signal (unity gain, open loop), min		1.0 MHz	1 MHz	3 MHz
	f_s	Large signal: full output (undistorted) min		10 kHz	– –	200 kHz
	f_p	full output (peak-to-peak), min		– –	50 kHz	– –
	s_r	Slew rate		1.2 V/μSec	30 V/μSec (min)	10 V/μSec
	t_s	Settling time (0.1%)		20 μSec	15 μSec	6 μSec
Input Voltage Range	E_{CM}	Common mode (dc linear operation), min		±20 V	±|Vcc-15|V	±10 V
		(fault), abs max		±26 V	±150 V	±15 V
	E_D	Differential (between inputs), abs max		52 V	300 V	30 V
Input Voltage Offset	CMRR	Common mode rejection ratio (dc)		20,000	200,000	5000
	E_{os}	Initial (without external trim) @ 25°C		– –	±2 mV (max)	– –
	R_{os}	Zero adjustment		50 kΩrhst	1 kΩpot	1 kΩrhst
	E_{os} TC	Vs. Temperature (avg. -25 to +85°C), max		±20 μV/°C	±50 μV/°C	±35 μV/°C
	$\Delta E_{os}/\Delta t$	Vs. Time (per day)		±25 μV	±100 μV	±50 μV
	PSRR	Vs. Power Supply		±100 μV/V	±10 μV/V	±50 μV/V
Input Bias Current	I_B	Initial @ 25°C, max		±25 nA	-30 pA	-100 pA
	I_BTC	Vs. Temperature (avg. -25 to +85°C), max		±1 nA/°C	±3 pA/°C [1]	10 pA/°C [1]
	$\Delta I_B/\Delta V_{CC}$	Vs. Power Supply		±5 nA/V	±0.5 pA/V	±5 pA/V
	$\Delta I_B/\Delta t$	Vs. Time (per day)		– –	– –	– –
	I_D	Difference (tracking)		±2 nA	±10 pA	±20 pA
Input Impedance	Z_D	Differential		250 kΩ||6pF	10^{11} Ω ||10pF	10^{11} Ω||5pF
	Z_{CM}	Common mode (either input to common)		50 MΩ||5pF	10^{12} Ω ||10pF	10^{11} Ω||6pF
Noise (Referred to input)	e_n	Flicker (0.016 to 1.6 Hz)	Voltage p-p	5 μV	25 μV	8 μV
	i_n		Current p-p	150 pA	– –	1 pA
	e_n	Midband (1.6 to 160 Hz)	Voltage rms	1 μV	8 μV	5 μV
	i_n		Current rms	50 pA	– –	1 pA
	e_n	Broadband (160 Hz to 16 kHz)	Voltage rms	0.9 μV	5 μV	5 μV
	i_n		Current rms	40 pA	0.5 pA	3 pA
Power Requirements	±V_{CC}	Nominal Supply Voltage		±26 V	±120 V	±15 V
		Voltage range		±22 to ±28 V	±40 to ±150 V	±12 to ±18 V
	I_{CC}	Current: quiescent, max		±7 mA	±10 mA	±10 mA
		full load, max		±12 mA	±30 mA	±40 mA
Temperature Range (°C)	T_o	Operating		-25 to +85	-25 to +85	-25 to +85
	T_s	Storage		-55 to +125	-55 to +125	-55 to +100
Mechanical See pages 38-43		Outline drawing		A1	G4	A1
		Socket		NSK-20($1.60)	6043($3.50)	NSK-20($1.60)
Price		Quantity (1-9)		$24.00	$95.00	$35.00
		(10-24)		$23.00	$91.00	$33.50

NOTES
1. Slope at +25°C, doubles each +10°C
2. Short circuit = ±80 mA
3. This socket not supplied by Teledyne Philbrick, available from Barnes Corp., Lansdowne, Pa.

DISCRETE | MICROCIRCUIT

HIGH CURRENT ◄► BATTERY OPERATION - LOW DRAIN

	1017 Economy High Power	**1016** High Speed High Power	**Q-200** Micropower	**1006** FET, Micropower	**140410 140411** Micropower	**1402 140202** FET, Battery
	±10 V	±|Vcc-5|V	±|Vcc-1.5|V	±|Vcc-1.2|V	±|Vcc-3|V	±|Vcc-2|V
	±125 mA	± 100 mA	±3 mA	±1 mA	±2 mA	±2 mA
	20,000	300,000	40,000	10,000	25,000	10,000
	40,000	750,000	– –	25,000	– –	– –
	1 MHz	10 MHz (typ)	150 kHz	600 kHz (typ)	0.1 MHz	1.0 MHz
	15 kHz	1 MHz	– –	50 kHz	5 kHz	70 kHz
	18 kHz	1.3 MHz	1 kHz	– –	8 kHz	– –
	1 V/μSec	75 V/μSec	3 V/mSec	0.7 V/μSec	0.3 V/μSec	3 V/μSec (min)
	– –	1 μsec (0.01% typ.)	500 μSec	6 μSec	50 μSec	– –
	±11 V	±|Vcc-5|V	±|Vcc-1.5|V	±|Vcc-2.2|V	±|Vcc-4|V	±|Vcc-3|V
	±15 V	±Vcc	±Vcc	±Vcc	±Vcc	±Vcc
	30 V	2 Vcc	2 Vcc	2 Vcc	2 Vcc	2 Vcc
	1000	100,000	10,000	2,000	50,000	6500
	±6 mV	– –	±1 mV	±1 mV	±5 | 1 mV	±3 | 1 mV
	1 MΩpot	50 kΩpot	1 MΩpot	1 kΩpot	1 MΩpot	1 kΩpot (opt'l.)
	±45 μV/°C	±20 μV/°C	±20 μV/°C	±50 μV/°C	±20 | 10 μV/°C	±50 | 10 μV/°C
	– –	±50 μV	±20 μV	±25 μV	±50 μV	±25 μV
	±50 μV/V	±10 μV/V	± 200 μV/V	±200 μV/V	±10 μV/V	±400 μV/V
	±100 nA	±5 nA	-25 nA	-50 pA	+30 nA	−30 pA
	±3 nA/°C	±1 nA/°C	±0.4 nA/°C	5 pA/°C [1]	±0.5 nA/°C	±3 pA/°C [1]
	±25 nA/V	±0.1 nA/V	±5 nA/V	– –	±350 pA/V	±3 pA/V
	– –	– –	±2 nA	– –	– –	±1 pA
	– –	±2 nA	±5 nA	±10 pA	±7 nA(max)	±10 pA
	210 kΩ||10pF	0.5 MΩ||6pF	4 MΩ||10pF	10^{11} Ω||6pF	4 MΩ||10pF	10^{12} Ω||4pF
	200 MΩ||4pF	1000 MΩ||6pF	500 MΩ||10pF	10^{11} Ω||6pF	100 MΩ||10pF	10^{12} Ω||10pF
	3 μV	5 μV	10 μV	6 μV	1 μV	6 μV
	220 pA	100 pA	60 pA	0.2 pA	15 pA	0.1 pA
	1 μV	2 μV	10 μV	2 μV	0.3 μV	2 μV
	60 pA	60 pA	10 pA	1 pA	3 pA	1 pA
	1 μV	0.9 μV	15 μV	3 μV	1 μV	2 μV
	90 pA	100 pA	10 pA	2 pA	10 pA	2 pA
	±15 V	±15 V	±4.5 V	±2.7 V	±4.5 V	±15 V
	±12 to ±18 V	±8 to ±28 V	±2.5 V to ±15 V	±2 to ±16 V	±2 to ±18 V	±4 to ±24 V
	±15 mA	±25 mA	±65 μA	± 200 μA	±75 μA	±1.0 mA
	±140 mA [2]	±125 mA	±3.1 mA	±1.2 mA	±1.2 mA	±3.0 mA
	-25 to +85	-25 to +85	-25 to +85	-25 to +85	-25 to +85	-25 to +85
	-55 to +125	-55 to +125	-55 to +100	-55 to +85	-55 to +125	-55 to +125
	A1	G1	A1	A1	S4	TO-8
	NSK-20($1.60)	NSK-9($2.50)	NSK-20($1.60)	NSK-20($1.60)	See Note 3	US-Q ($3.50)
	$35.00	$70.00	$30.00	$35.00	$49.00 | 56.00	$50.00 | 85.00
	$33.50	$68.00	$28.50	$33.50	$47.00 | 54.00	$48.50 | 83.50

Specifications listed left to right correspond to model numbers top to bottom above.

Selected versions are available on all models, consult factory.

Group VI
General Purpose Linear Microcircuits

"OPTIMIZED 741's"

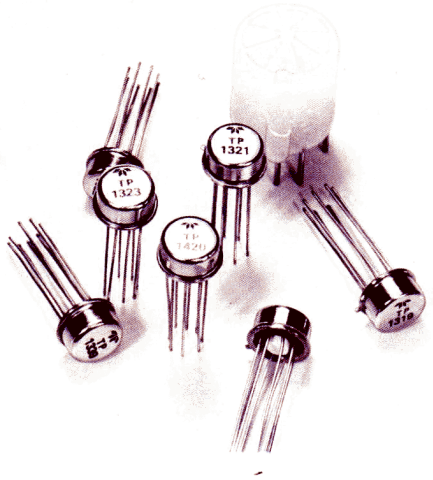
By utilizing the "optimized 741's", such problems as lower system accuracy, increased design time and higher component costs are effectively eliminated. Further, for special purpose requirements, these microcircuits can be selectively given even higher guaranteed performance.

Specifications typical at 25°C with nominal power supply supply, unless otherwise indicated.

			1339 General Purpose	1319 High Performance Low Drift	1321 Wideband High Input Impedance
Output Range	E_o	Voltage, min.	±10 V	±10 V	±10 V
	I_o	Current, min	±10 mA	±5 mA	±10 mA
Voltage Gain	A_o	Rated load, min	15,000	50,000	80,000
Frequency Response (Inverting)	f_t	Small signal (unity gain, open loop), min	1 MHz	1 MHz	100 MHz [2]
	f_p	Large signal: full output (peak-to-peak), min	10 kHz	8 kHz	320 kHz
	s_r	Slew rate	34 V/μsec [1]	0.6 V/μsec	35 V/μsec
	t_s	Settling time (0.1%)	—	—	—
Input Voltage Range	E_{CM}	Common mode (dc linear operation), min	±11 V	±12 V	±12 V
	E_D	Differential (between inputs), abs max	20 V	24 V	24 V
	CMRR	Common mode rejection ratio (dc)	100,000	30,000	100,000
Input Voltage Offset	E_{os}	Initial (without external trim) @25°C	±2 mV	±5 mV	±5 mV
	R_{os}	Zero adjustment	—	10 kΩ rhst	100 kΩ pot
	E_{os}TC	Vs. Temperature (avg. 0 to 70°C)	±5 μV/°C	±6 μV/°C	±30 μV/°C
	PSRR	Vs. Power Supply	—	10 μV/V	30 μV/V
Input Bias Current	I_B	Initial @ 25°C, max	1 μA	250 nA	±25 nA
	I_D	Offset (tracking)	20 nA	3 nA	5 nA
	I_DTC	Offset vs. temp (avg. - 25 to +85°C), max	±200 pA/°C	±30 pA/°C (typ)	0.8 nA/°C
Input Impedance	Z_D	Differential	300 kΩ	2 MΩ	300 MΩ
	Z_{CM}	Common mode (either input to common)	—	—	1000 MΩ
Noise	e_n	Midband Voltage rms (10 Hz to 10 kHz)	2 μV	1μV	1 μV
Power Requirements	$\pm V_{CC}$	Nominal supply voltage	±15 V	±15 V	±15 V
		Voltage range	±3 to ±18 V	±8 to ±22 V	±8 to ±22 V
	I_{CC}	Current: quiescent, max.	±7 mA	±3 mA	±4 mA
		full load, max	±12 mA	±8 mA	±14 mA
Temperature Range °C	T_o	Operating	0 to 70	0 to 70	0 to 70
	T_s	Storage	−65 to +150	−65 to +150	−65 to +150
Mechanical See pages 38-43		Outline drawing	TO-99	TO-99	TO-99
		Socket	*	*	*
Price		Quantity (1–9)	$2.75	$6.00	$15.00
		(10–24)	$2.75	$5.75	$14.25

NOTES
1. At gain of 100, 4.2 V/μsec at A=1
2. G X BW at A=3
3. Average temperature drift −25 to +85°C

* Socket not supplied by Teledyne Philbrick



	1322 High Slew Rate	1323 Low Power General Purpose	1413 Low I_{BIAS}	1420 FET, General Purpose
	±10 V	±12 V	±11 V	±10 V
	±10 mA	±10 mA	±5 mA	±5 mA
	10,000	200,000	15,000	20,000
	20 MHz	1 MHz	0.5 MHz (typ)	100 kHz
	1.2 MHz	25 kHz	10 kHz	2 kHz
	120 V/μsec	20 V/μsec	0.6 V/μsec (min)	0.3 V/μsec
	200 nsec	10 μsec	20 μsec	– –
	±10 V	±10 V	±12 V	±10 V
	30 V	– –	– –	30 V
	30,000	200,000	20,000	10,000
	±10 mV	±5 mV	±2 mV	±15 mV
	20 kΩpot	1 MΩpot	10 kΩpot	10 kΩpot
	±30 μV/°C	±30 μV/°C	±20 μV/°C [3]	±50 μV/°C [3]
	30 μV/V	10 μV/V	– –	200 μV/V
	±250 nA	±40 nA	+10 nA	-50 pA
	20 nA	2.5 nA	0.5 nA	10 pA
	±0.5 nA/°C	0.5 nA/°C	– –	Doubles/10°C
	100 MΩ	50 kΩ	10 MΩ‖5pF	10^{11} Ω‖3pF
	1000 MΩ	– –	100 MΩ‖5pF	10^{11} Ω‖3pF
	1 μV	10 μV	10 μV	1 μV
	±15 V	±15 V	±15 V	±15 V
	±8 to ±20 V	±5.5 to ±20 V	±3 to ±18 V	±12 to ±18 V
	±6 mA	±80 μA	±3 mA	±4 mA
	±16 mA	±10 mA	±8 mA	±9 mA
	0 to 70	0 to 70	-25 to +85	-25 to +85
	-65 to +150	-65 to +150	-55 to +125	-65 to +150
	TO-99	TO-99	TO-99	TO-99
	*	*	*	*
	$20.00	$15.00	$10.00	$19.00
	$19.25	$14.25	$ 9.50	$18.25

Selected versions are available on all models, consult factory.

Instrumentation Amplifiers

FEATURES

- High CMRR
- High Input impedance
- Low voltage offset
- Low bias current
- Excellent linearity
- 100 mA output (4251)
- 25 kHz response

APPLICATIONS

- Biomedical probes
- Strain gages
- Thermocouples
- Pressure transducers

DESCRIPTION

Models 4251 and 4252 instrumentation amplifiers are ideal for precision amplification of low-level signals in the presence of high common mode noise. Biomedical probes, strain gages, thermocouples and pressure transducers are just a few of the applications where the high CMRR, high input impedance, low voltage offset, low bias current and excellent linearity of these amplifiers are of great significance.

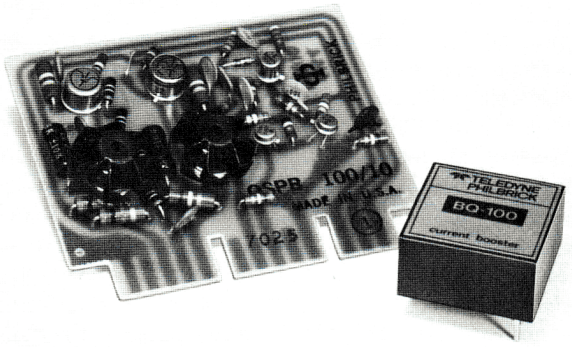
Both models are gain programmable with a single resistor over the range of 1 to 1000. Offset voltage is externally adjustable to zero. An output sense terminal is provided, thus allowing the amplifier feedback to be taken precisely at the load point. This terminal is also useful for adding a current booster inside the loop (such as Model 2001), or for a transconductance application where the output current is proportional to the input voltage.

Another feature of Models 4251 and 4252 is the CMRR adjust terminal, which allows external trimming of the common mode rejection ratio at the exact gain and frequency desired. This terminal also serves as a reference point for the amplifier output, and output offsets of up to ±10 volts can be introduced.

SPECIFICATIONS
(Typical at 25°C, nominal supply voltage unless otherwise indicated)

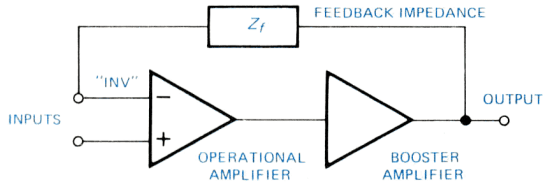
GAIN	
Gain Range (Adj. with Ext. Res.)	1–1000
Gain Programming	$A = 1 + \frac{20k\Omega}{R}$
Gain dc Nonlinearity, Max	±0.01%
Gain dc Nonlinearity vs Temperature (A = 100)	0.001%/°C
INPUT CHARACTERISTICS	
Input Impedance - Differential	50 MΩ
Input Impedance - Common Mode, Min	30 MΩ
Input Voltage Range Common Mode, Min	±10 V
Input Voltage Range Differential, Min	±10 V
OFFSETS AND NOISE	
Input Offset Over Range of Gain, Max	±3 mV
Input Bias Current (Offset @ either Input), Max	30 nA
Input Bias Current vs Temperature, Max	±3 nA/°C
Input Offset Current	5 nA
Output Voltage Offset vs Temp. A = 1000, Max	5 mV/°C
Input Voltage Offset vs Temp.	2 μV/°C
Output Voltage Offset vs Temp. A = 1, Max	50 μV/°C
Output Noise (dc – 10 kHz) A = 1000, Max	8 mV rms
Output Noise (dc – 10 kHz) A = 1	5 μ V rms
COMMON MODE REJECTION (dc–100 Hz)	
A = 10, 10k Source Unbalance, Min	60 dB
A = 10, Balanced Source, Min	80 dB
A = 1000, Balanced Source	110 dB
FREQUENCY RESPONSE	
Small Signal, A = 100, ±1% Accuracy, Min	25 kHz
Small Signal, A = 100 ±3 dB Accuracy, Min	50 kHz
Output Slew Rate, A = 100, Min	0.6 V/μsec
OUTPUT CHARACTERISTICS	
Rated Output Voltage, Min	±10 V
Rated Output Current, Min 4251	±100 mA
Rated Output Current, Min 4252	±5 mA
Output Impedance, dc to 1 kHz, 4251	0.002Ω
Output Impedance, dc to 1 kHz, 4252	0.05Ω
POWER SUPPLY REQUIREMENTS	
Supply Voltage, Rated Specs	±15 Vdc
Supply Voltage, Derated Specs	±14 to ±16 Vdc
Supply Current, Quiescent, Max	±15 mA
Supply Current, at Rated Load, Max 4251	±115 mA
Supply Current, at Rated Load, Max 4252	±20 mA
TEMPERATURE RANGE (in degrees C)	
Operating Rated Specs	–25 to +85
Operating Derated Specs	–40 to +85
Storage	–55 to +100
PACKAGE & SOCKET	G4-6118 ($5)
PRICE (1 – 9) 4251-4252	$95.00 $75.00
(10–24) 4251-4252	$91.00 $71.50

Booster Amplifiers



By definition, a Booster is a power amplifier. A current booster is used when the output current is too small to drive the necessary load. Voltage boosters are also available to extend output voltage capabilities of the standard 10 Volt operational amplifier. (See OSPB-100/10)

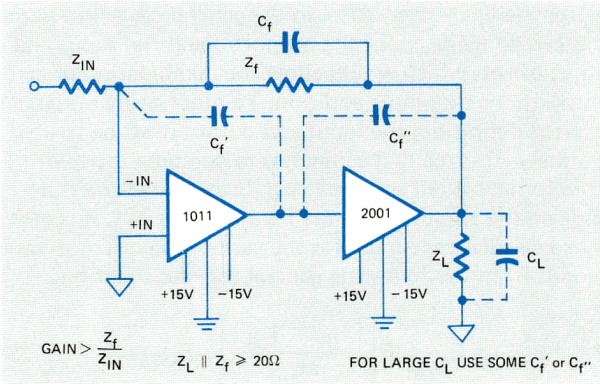
Because the booster is normally connected inside the operational amplifier's negative feedback loop, its contribution to drift, linearity, and gain error is negligible.

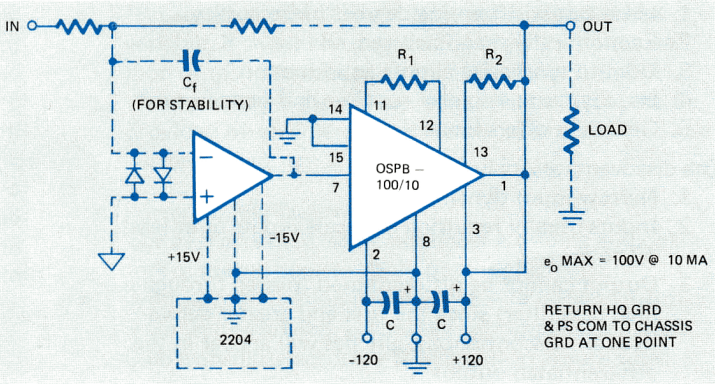


Specifications typical at 25°C with nominal power supply, unless otherwise indicated.

		BQ-100	2001	OSPB-100/10
OUTPUT	Voltage, gtd. min.	±10 V	±10 V	±100 V
	Current, gtd. min.	100 mA	500 mA	1.5 mA (10 mA)*
VOLTAGE GAIN (DC open loop)	At rated load, gtd. min	0.95	0.90	19
	Current gain, gtd. min	2000	40,000	
FREQUENCY RESPONSE	Full output (no distort.) gtd. min	400 kHz	80 kHz	10 kHz
	Rate limit	35 V/μSec	10 V/μSec	7 V/μSec
INPUT VOLTAGE OFFSET	Initial @ 25°C	±0.3 V	±0.3 V	±0.1 V
INPUT IMPEDANCE	Pos. or neg. input to common	600 kΩ	1 MΩ	1 MΩ
OUTPUT IMPEDANCE	Output to common	3 Ω	1 Ω	500 Ω
	Nominal supply voltage	±15 V	±15 V	±120 V
POWER REQUIREMENTS	Voltage range	±12 to ±16 V	±12 to ±16 V	±100 to ±125 V
	Current (quiescent), max	±15 mA	±50 mA	±3.5 mA
	(full load), max	±120 mA	±550 mA	±6 mA (±15 mA)*
TEMPERATURE RANGE (in °C)	Operating	-25 to +85	-25 to +65	-25 to +85
	Storage	-55 to +100	-55 to +100	-55 to +85
CASE STYLE & SOCKET		AS2, NSK-20	G1, NSK-9	SP, QS-15
PRICE	(1-9)	$40.00	$65.00	$98.00
	(10-24)	$31.50	$60.00	$76.50

*Specifications shown in parenthesis apply when external boost resistors are used. See OSPB-100/10 data sheet.





NONLINEAR FUNCTION MODULES

Introduction to Nonlinear Circuits

Many natural processes are neither linear nor quantitative but behave in continuously smooth, nonlinear ways. To the systems engineer faced with solving nonlinear applications, Teledyne Philbrick offers a wide variety of circuit modules. Armed with a basic knowledge of operational amplifier theory, the engineer can easily understand and apply these nonlinear function modules to extend the mathematical versatility of op amps and provide exponential, transcendental, and high order functions.

Just as the gain is varied in a linear circuit by varying the ratio of the feedback impedance to the input impedance, so does the ratio of impedances for nonlinear circuits, but instead of being a fixed value it varies as some predetermined function, determined by the input amplitude. Also, nonlinear function circuits have basic limitations the same as operational amplifiers.

WHAT IS A NONLINEAR CIRCUIT?

A circuit is nonlinear when the output is not linearly proportional to its input. Obviously, all digital circuits and amplifiers with unintentional distortion fall in this category; but these are not the products to be discussed here. Rather, we are interested only in those amplifiers having intentional, accurately predetermined, stable distortion. Usually for circuit modules the shape of the distortion can be accurately described by a simple and useful mathematical expression.

The products that we are mainly interested in are logarithmic devices, sine and cosine functions, square law modules, and multiplier/divider modules. Also available are modules whose output can be user-adjusted to virtually any function of the input. These are known as variable function modules.

VARIOUS CIRCUIT TECHNIQUES

There are two fundamental techniques which are used in generating nonlinear functions, and each technique has its own unique characteristics. Historically, the first method of generating nonlinear functions was the piece-wise, straightline approximation technique using diode-resistor networks which resulted in several advantages and disadvantages. The advantages offered by this technique are as follows:

1. Made fast with varying degrees of "accuracy."
2. Economically manufactured.
3. Used to synthesize almost any function.
4. Usually quite stable versus time and temperature.
5. Generally offers low noise.

The disadvantages include:

1. Narrow input dynamic range.
2. Inputs usually requiring full-scale inputs of at least 10 volts.
3. Output cannot be differentiated (passed through a high pass filter) since the first and greater derivatives are discontinuous, glitches will appear in the differentiated output.

The second technique used in generating nonlinear functions is the continuous method which uses the nonlinear voltage/current characteristics of semiconductor materials and junctions such as used in log modules and transconductance multiplier/divider modules. The advantages offered by this second technique are as follows:

1. Wide input dynamic range.
2. Usually built compactly.
3. Cost can be very low.
4. Speed is moderate.
5. Output can be differentiated.

The disadvantages include:

1. Elaborate temperature compensation, internal or external, is required.
2. High output noise for certain functions.
3. Choice of desired functions is limited.

The first step in choosing a nonlinear module is to determine which of the two methods of nonlinear generation is most suitable for the application. Of course, some applications require modules with performance beyond the present state-of-the-art. If this is the case, reduced performance or another method should be considered.

WHAT IS ACCURACY?

Next to cost, the most important consideration for the customer engineer is some figure of merit, usually dubbed "accuracy," which he can use to calculate his overall system error. "Accuracy," however, is a rather nebulous term when applied to intentionally nonlinear operations. The term is primarily suited for defining error of straight-line phenomenon in terms of only **three** simple parameters: **offset, slope,** and **deviations** from straight-line. With linear circuits it is easy to select a reference to which errors can be compared in order to generate an accuracy specification. However, for nonlinear operations, it is necessary to look at the general case from which accuracy is derived, using some simple assumptions.

In the general case, error must be defined in terms of three more complex parameters: **offsets, curvature,** and **deviation** from ideal curvature, whereas the curvature is just a straight-line for the linear case. Also, in the general case, **no** assumptions can be made about the proportionality of input and output offsets which would allow the combination of error contributions by simple addition. To more easily understand the error definition, the input and output must be treated separately. It is really meaningless to combine the two errors for an overall accuracy specification because it depends on the amplitude of the input. As a result, it is necessary to calculate accuracy for the various regions or decades of input from the following general transfer function:

$$E_o = E_{o_{ref}} F\left[\frac{(I_{in} \pm I_{os})}{\pm I_{ref}}\right] - E_{oos}$$

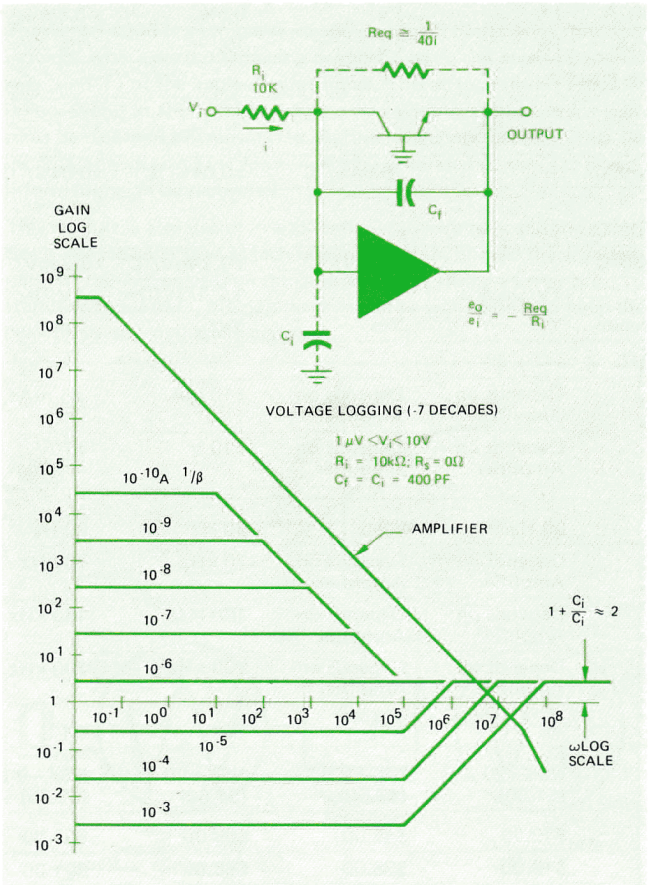
For functions with more than one input variable, such as log-ratio circuits, multipliers, and dividers, each of the inputs must be associated with its own, like-dimensioned (voltage/current), offset and reference.

The output and its tolerance can be easily calculated under any condition with the above relationship as a foundation, provided the magnitude, tolerance, temperature coefficient, and power supply dependence of both the input and output references and offsets are known. If the deviation from true function conformity is also considered, probable error and worst case errorbands can be calculated over the entire input range in any application. In other words, the most important specifications to the user is a unique combination of those specifications which take into account the user's particular requirements including **dynamic range, temperature range, power supply variations,** and any other relevant considerations.

LIMITATIONS WITH FREQUENCY

We have only been looking at the steady-state or low-frequency operation in determining optimum performance. For high frequency operations, additional considerations are necessary.

For linear systems, the simple parameters of small-signal gain-bandwidth product and output slewing rate are generally sufficient, since the gain is constant, and, therefore, bandwidth is constant. However, in nonlinear circuits, the small-signal gain (or slope) is a function of input level. Therefore, since the gain-bandwidth product tends to remain constant, the small-signal bandwidth must change as a function of input level. Example:



For an amplifier with a 10 MHz gain-bandwidth product at a current level of 1 nA, the maximum operating frequency is approximately equal to 100 Hz.

Similarly, the slewing rate tends to be proportional to small-signal bandwidth. Therefore, slewing rate also changes as a function of input level. Generally, slewing time from one level to another level becomes proportional to the small-signal bandwidth at the final level. In other words, if it takes a certain amount of time in seconds to go from 1 nA to 10 nA then it will take approximately 10 times longer to go from 10 nA to 1 nA. One usually will find the small-signal bandwidths and slewing times are specified at several input levels.

PARAMETER DEFINITION AND MEASUREMENT GUIDE

SIX PARAMETERS are common to all nonlinear function elements and operators, and their significance should be fully appreciated before any attempt is made to evaluate or predict their performance or the performance of a circuit using them.

- **Performance Range**
  States the values of input signal levels for which the specified input/output relationship will be maintained to the specified accuracy. Several ranges are possible, depending on accessories, the amplifier, and the circuit used.

- **Accuracy**
  Is stated in terms of conformance with the specified input/output function. It is frequently given in terms of the maximum per-unit or percent error, under "standard" conditions listed in the accuracy specification, and the error expression is usually a fairly simple function of the input signal level.

- **Temperature Coefficient**
  Relates the (steady-rate) ambient temperature to the worst-case error (at equilibrium, all other conditions being standard) in the input/output function.

- **Response Error**
  Relates the dynamic (small signal or transient) performance of the nonlinear element or operator to its dc (steady-state) performance; either by stating the (sinusoidal-wave) frequency rate over which the "standard conditions" performance will be maintained, or by stating a slewing rate.

- **Excitation Dependence**
  All nonlinear elements and operators require a near perfect signal source. When voltage is the independent variable, it should be supplied by the very low closed-loop output impedance of an Operational Amplifier. When current is the independent variable, it should be provided by an Operational Amplifier programmed as a current pump.

- **Power Supply Dependence**
  For *best* accuracy, some nonlinear elements and operators requiring power supply potential(s) — i.e.: synthesized-function designs — should obtain (them) from well-regulated, accurately set supplies; generally, 0.05% absolute accuracy is required to ensure rated performance.

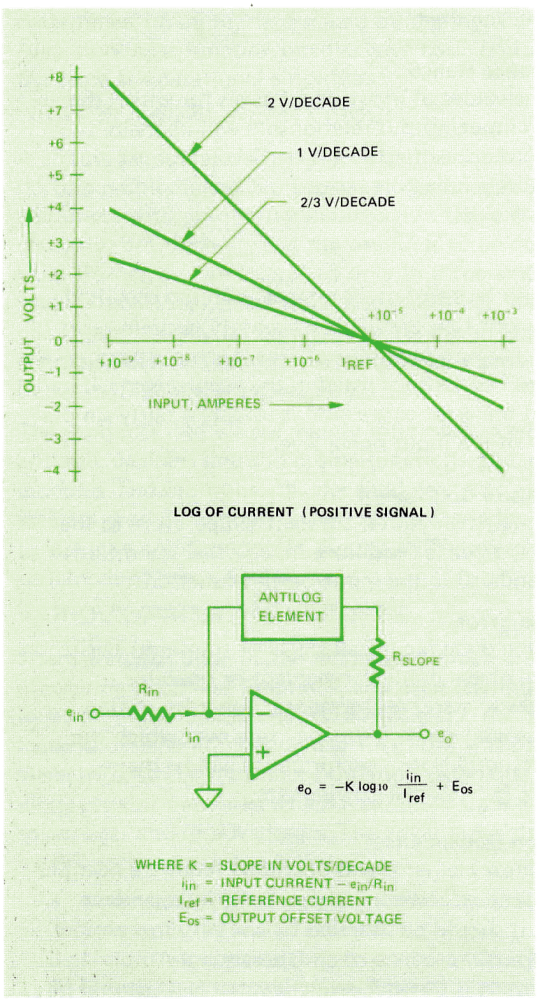
MODELS 4357/4358 PPL4-N/P 4350/4351 4361

Logarithmic Amplifiers

FEATURES

- Wide Dynamic Range
- Temperature Compensated
- Superior Logarithmic Conformity
- Very Low Cost (Models 4357/4358)
- Log or antilog obtained with built-in Operational Amplifier (Models 4350/4351)
- Adjustable Gain and Reference Current Controls (Models PPL4-N/P)
- Log of Current Ratio (Model 4361)

BASIC CIRCUIT



Teledyne Philbrick logarithmic amplifiers provide an output proportional to the log or antilog of their input signal. (Model 4361 provides an output proportional to the log of its input signal only.) Each unit is complete with a built-in operational amplifier and a precision antilog element, and requires only operating power plus input and output connections in order to perform its log or antilog computations.

Models 4357/4358, when utilized with two low bias current operational amplifiers will produce an accurate, temperature-compensated logarithmic ratio amplifier calibrated to 1 volt per decade input change which responds to 6 decades of input current or 4 decades of input voltage.

Models PPL4-N/P when operated with one low bias current operational amplifier, produces an accurate, temperatue-compensated logarithmic amplifier allowing adjustment of reference current and slope (volts per decade input change).

Model 4350 computes the logarithm of a positive voltage or current or solves for the positive antilog of an input voltage, while the Model 4351 computes the logarithm of a negative voltage or current or solves for the negative antilog of an input voltage.

Model 4361 is a logarithmic module designed to give an output voltage proportional to the log ratio of its input currents. The inputs require negative current sources in the range of -10^{-9} to -10^{-3} amperes making it ideally suited for phototube ratio applications circuits. This unit is complete with a built-in operational amplifier and precision temperature compensated log ratio element and has a grounded metal case to shield out unwanted electrostatic and electromagnetic noise.

SPECIFICATIONS

	4357/4358	PPL4-N/P	4350/4351	4361
DYNAMIC RANGE				
Current	120 dB	120 dB	120 dB	120 dB
Voltage	80 dB	80 dB	80 dB	N/A
ACCURACY 1% OF READING (Referred to Input)				
1 nA to 10 nA	1%	2%	1%	0.5%
10 nA to 100μA	1%	1%	0.5%	0.5%
100μA to 1mA	1%	2%	1%	1%
TEMPERATURE DRIFT				
Scale Factor				
+10 to +60°C	±0.04%/°C			
−25 to +85°C		±0.04%/°C	±0.04%/°C	±0.04%/°C
Offset				
+10 to +60°C	±0.1 mV/°C			
−25 to +85°C		±5 mV/°C	±0.3 mV/°C	±0.3 mV/°C
SLOPE Fixed	1V/Decade		1,2,2/3V/Dec	1V/Dec
Adjustable	Yes	Yes	Yes	Yes
RATED OUTPUT				
Current	Depends on Amplifier	Depends on Amplifier	±10 mA	±5 mA
Voltage	Depends on Amplifier	Depends on Amplifier	±10 V	±10V
BANDWIDTH				
1 nA	80 Hz	80Hz	80 Hz	80 Hz
1.0μA	Depends on Amplifier	Depends on Amplifier	70 kHz	70 kHz
10μA	Depends on Amplifier	Depends on Amplifier	180 kHz	180 kHz
1 mA	Depends on Amplifier	Depends on Amplifier	200 kHz	200 kHz
CASE STYLE	A6	AS2	G2	G1
SOCKET	NSK−20 ($1.60)	US−PP ($3.50)	NSK−20 ($1.60)	NSK−9 ($2.50)
PRICE 1−9	$19.00	$46.00	$98.00	$95.00
10−24	$18.00	$38.00	$88.00	$91.00

MODEL 4356—AC Logarithmic Amplifier

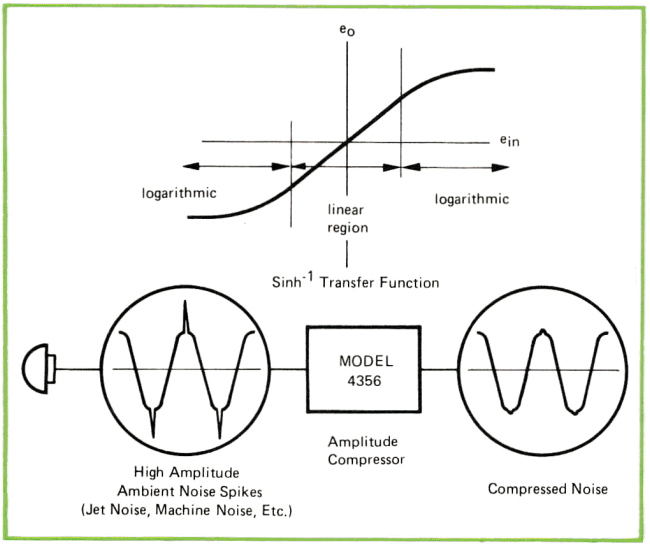
FEATURES

- Unique Nonlinear Module, Sinh^{-1} Linear through Zero, then Three Decades of AC/DC Logging
- Speech Compression — 40 dB of Compression
- Wide Bandwidth — DC to 10 kHz

DESCRIPTION

The Model 4356 is a temperature-compensated, continuous function network whose output voltage is proportional to the inverse hyperbolic sine (sinh^{-1}) of the applied input signal. This ac logarithmic amplifier is very useful in applications where a very wide dynamic range signal must be recorded or transmitted. By the interconnections on the module, the inverse function can also be generated so that the exact information can be recovered.

This module is also useful in applications where a nonsaturating amplifier is needed such as in speech communication. Should the ambient noise be much greater than the desired input causing a linear preamplifier to saturate, the nonlinear amplifier will operate to keep the peak levels approximately constant.



SPECIFICATIONS

OUTPUT FUNCTIONS

Sinh^{-1} $K\sinh^{-1}\frac{I_{in}}{2i_r}$	I_{in} = 0 to ±5 mA, i_r = 1 μA ±2%
Log $_{10}$ $2.3\,K\log_{10}\frac{I_{in}}{I_r}$	I_{in} = 3 μA to ±5 mA, I_r = 1 μA ±2%
(K = 1.000)	Adj. with ext Rf

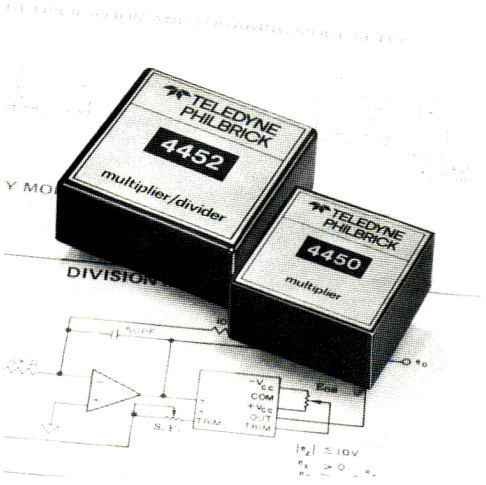
CONFORMITY (100 Hz)

Sinh^{-1} (0.1 μA to ±5 mA)	0.5 dB
Log (±3 μA to ±5 mA)	0.5 dB

COMPRESSION	40 dB
INPUT	
Voltage	±10 V
Current	±5 mA
OUTPUT	
Voltage	±10 V
Current	±5 mA
BANDWIDTH	
Large Signal	10 kHz
TEMPERATURE STABILITY	
Offset	±2 mV/°C
Scale Factor	±0.01%/°C
Reference	±0.1%/°C
TEMPERATURE RANGE	0°C to +70°C
POWER REQUIREMENT	
Voltage	±15 V
Current	±7 mA
CASE STYLE	E1
SOCKET	NSK-14 ($1.70)
PRICE	
(1–9)	$90.00
(10–24)	$78.00

MODELS 4450/4452

Multiplier/Dividers



FEATURES

- Small Size
- 4-Quadrant Operation
- High Input Impedance (4452)
- No External Amplifiers Required (4452)
- 1% Accuracy guaranteed to 10 kHz for ±10 Volt Signals (Model 4450)

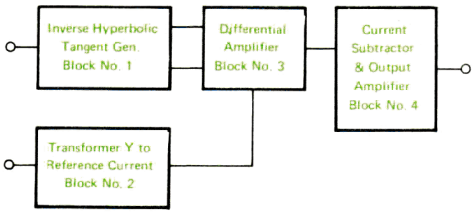
BASIC CIRCUIT

BLOCK NO. 1 Provides the desired nonlinear function, $\tanh^{-1}$. This is accomplished by establishing a differential current, forcing it through diodes and extracting the differential voltage. This output is then applied to the input of the differential amplifier.

BLOCK NO. 2 Transforms the input voltage, Y, into a reference current, which modulates the emitter current of the differential pair.

BLOCK NO. 3 The basic differential amplifier is made up of two pairs of cross-coupled transistors which are essential in four-quadrant operations.

BLOCK NO. 4 Is comprised of a subtractor circuit to convert the differential current output to single ended output and the output operational amplifier for current-to-voltage transformation.



Basic Block Diagram for Variable Transconductance Multiplier

DESCRIPTION

Like the operational amplifier, the analog multiplier has graduated from its specialized role in analog computers and is now finding wider applications as a circuit component. Mathematically, the multiplier provides a natural extension to the analog capabilities of the operational amplifier. With operational amplifiers, the circuit designer can amplify, add, subtract, integrate, or differentiate by adding a few external components. When using multipliers, the designer also has the capability of multiplying, dividing, squaring, cubing, or performing square and cube-roots. As a result, the application possibilities are virtually unlimited when using various combinations of multipliers, operational amplifiers, and discrete components.

Models 4450 and 4452 are true four-quadrant, low-cost multipliers with outputs representing the instantaneous product of the two input signals. These units are very useful in applications requiring multiplying, dividing, squaring, square-rooting, cubing, and cube-rooting, etc. When used as a divider, Model 4450 must be connected to an external operational amplifier, while Model 4452 can function as a multiplier or divider, depending on external connections.

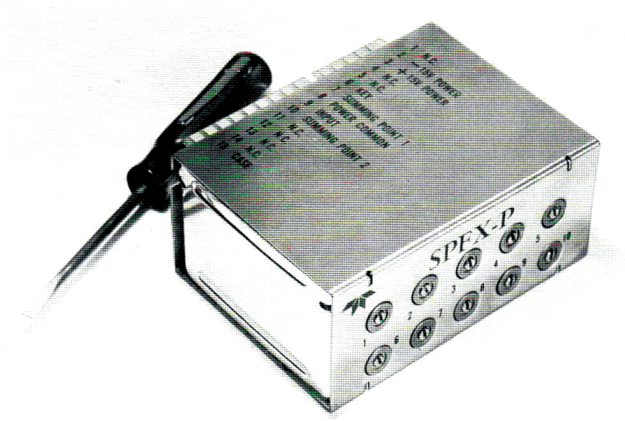
Because of the variable-transconductance technique used in the design of these multipliers, the error curve is very smooth; unlike that of the quarter-square and triangle-averaging circuits. All models have provisions for externally trimming the scale factor and offset errors for maximum performance.

SPECIFICATIONS

		4450	4452
OUTPUT FUNCTION			
Multiply		XY/10	−XY/10
Divide		–––	−10Z/Y
ACCURACY, % OF FULL SCALE TRIMMED			
4-Quadrant Operation		±1%	±2%
2-Quadrant Operation		–––	±1%
RATED INPUT			
Voltage—All Inputs		±10V	±10V
Impedance:	X—Input	25 kΩ	40 kΩ
	Y—Input	10 MΩ	30 kΩ
	Z—Input	–––	90 kΩ
RATED OUTPUT			
Voltage		±10V	±10V
Current		±2 mA	±5 mA
BANDWIDTH			
−3 dB Response		1 MHz	400 kHz
Full Output		100 kHz	50 kHz
1° Phase Shift		10 kHz	2 kHz
TEMPERATURE STABILITY			
Output Offset		±3 mV/°C	±3 mV/°C
TEMPERATURE RANGE		−25 to +85°C	0 to +70°C
POWER REQUIREMENTS			
Voltage		±15V	±15V
Current		±12 mA	±15 mA
CASE STYLE		A1	E5
SOCKET		NSK-20 ($1.60)	NSK-20 ($1.60)
PRICE	1–9	$75.00	$29.50
	10–24	$72.00	$28.20

MODELS SPFX-N/P

Variable Function Elements



FEATURES

- ±0.1% Accuracy
- Temperature Compensated (<100 ppm/°C)
- Wide Bandwidth
- Output Function Adjustable by User

DESCRIPTION

The Models SPFX-N and SPFX-P are variable function elements consisting of ten-section temperature compensated, diode-resistor networks having uniformly spaced, fixed breakpoints. The desired function is approximated by eleven straight line segments whose slopes are adjusted by potentiometers accessible on the top of the case. The transition from one segment to the next occurs at one volt intervals of input voltage, from 0.5V to 9.5 V. When used in the recommended operational amplifier circuits, they will accept an input voltage and generate an output voltage proportional to the desired function. The function generated may be, to a good accuracy, any arbitrary continuous function.

Separate versions of the SPFX are available for positive going (SPFX-P) and negative going (SPFX-N) inputs. One of each may be used in combination for the generation of functions having inputs of both signs. When necessary, closer approximation may be achieved by incorporating additional SPFX units (having the same polarity gender) to obtain finer subdivisions of the curve.

SPECIFICATIONS

OUTPUT FUNCTION		User Adjustable
Number of Segments		11
Breakpoint Spacing		10 Breakpoints, ea 1V @ 0.5 V
Accuracy when operated as square law device @25°C		$\lvert \delta i/i_{max} \rvert < 0.001$, where δi = (i actual) − (i desired)
INPUT		
Voltage		0 V to −/+10V
Current		50 μA max
OUTPUT		
Current		0 mA to −/+1 mA
BANDWIDTH		
−3 dB Response		> 500 kHz
TEMPERATURE STABILITY		<±100 ppm/°C
TEMPERATURE RANGE		−25°C to +85°C
POWER REQUIREMENTS		
Voltage		±15 V, ±0.01%
Current		±3.5 mA
CASE STYLE		SP
SOCKET		MB-SP ($10.00) Supplied
PRICE	(1–9)	$168.00
	(10–24)	$140.00

MODELS 4353/4354 4359/4360

Square Law Elements

FEATURES

- ±0.1% Accuracy
- Low Temperature Coefficient, <100 ppm/°C
- Wide Bandwidth

DESCRIPTION

The Models 4353, 4354, 4359 and 4360 are temperature compensated, straight-line approximation, ten-section diode function fitters that have break points adjusted to fit a square law relationship. They are designed to produce, to a good accuracy, an output voltage proportional to the square of the input voltage when connected to an appropriate operational amplifier. When used as the input network of an operational amplifier 4354 and 4360 take positive inputs and give a negative output. 4353 and 4359 take negative inputs and give a positive output. When used as the feedback element of an operational amplifier to extract square roots, 4354 and 4360 take negative inputs and result in a positive output, while 4353 and 4359 take positive inputs and give a negative output. Several applications using these modules include mean-square and RMS computation, odd-value or ab-squaring or rooting, and "quarter square" multiplication.

SPECIFICATIONS

OUTPUT FUNCTION		$Y = +/-X^2$
Number of Segments		11
Breakpoint Spacing		10 Breakpoints, each 1 V @ 0.5 V
Accuracy ①	(4353 & 4354)	±0.1% of full scale
	(4359 & 4360)	±0.25% of full scale
INPUT Voltage		0 to −/+10 V
Current		Constant −/+50 μA
OUTPUT		0 to −/+0.5 mA
BANDWIDTH		
1% Absolute Accuracy ②		100 kHz
TEMPERATURE STABILITY		Typically ±0.005%/°C
TEMPERATURE RANGE ③		−25°C to +85°C
POWER REQUIREMENT		±15V, ±1.5 mA
CASE STYLE		E5
SOCKET		NSK−20 ($1.60)
PRICE	(1–9) 4343 & 4354	$98.00
	(1–9) 4359 & 4360	$72.00
	(10–24) 4353 & 4354	$94.00
	(10–24) 4359 & 4360	$70.00

① Accuracy as a % of full scale includes gain, offset and linearity errors.
② Includes both phase shift and amplitude errors, measured at peak of 10V Triangle wave input
③ −55°C to +125°C operating temperature range available on models:
435301-435401 − $123.00 (1–9), $114.00 (10–24)
435901-436001 − $ 97.00 (1–9), $ 90.00 (10–24)

MODEL 4850

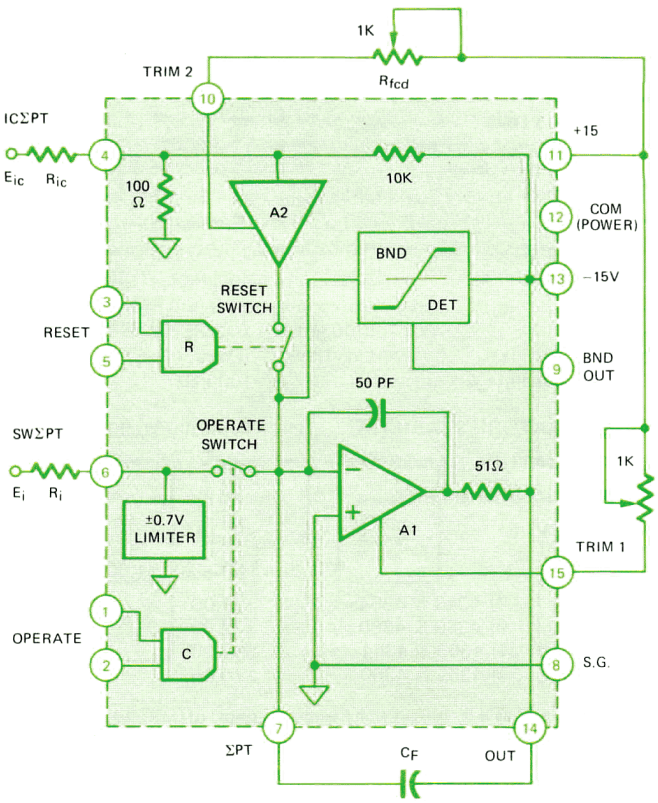
Three Mode Integrator

FEATURES

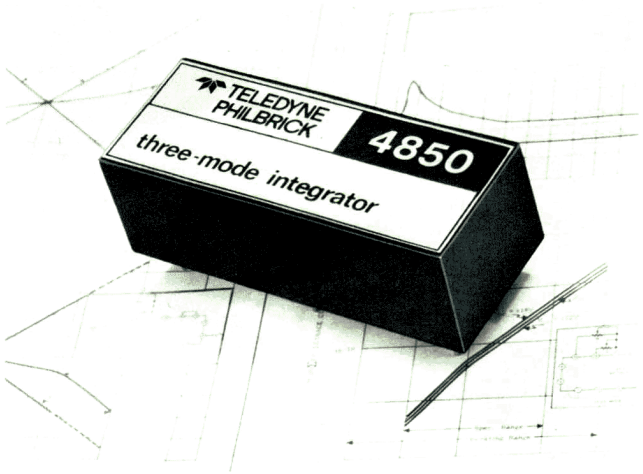
- Three Operating Modes, Reset/Integrate/Hold Track/Hold, Electronic Switch
- Command Signals can be of Positive or Negative Polarity
- Uncommitted Comparator Inputs Permit Compatibility to DTL/TTL Digital Logic and Gated Analog Logic
- Internal Bound Circuit Reduces Overdrive Recovery Time
- Accommodates Wide Range of Integrating Capacitors

DESCRIPTION

The Model 4850 three-mode integrator is a multi-purpose module with Reset, Integrate, and Hold modes of operation that can be controlled with external digital signals applied to two internal logic comparators. The comparator input command levels are compatible to many DTL, TTL logic levels; i.e., reference input may be elevated above common and interchanged respectively for inverse logic commands. These comparators control FET electronic switches that have excellent "feed-through" characteristics, combined with typical RDS-ON resistances of 20Ω for the Operate FET switch. These FET switches control the mode condition of the main FET amplifier, and the reset mode condition. A current amplifier drives the main amplifier. Both amplifiers and associated networks are in an internal reset (track) feedback loop. An internal bound circuit improves overdrive recovery with its output available. The operate mode gain configuration range is flexible with a wide integrating capacitor range of 0.001μF to 10μF. Input impedances in the order of 10^{11} Ω and ultra-low input bias currents in the FET amplifiers contribute to excellent three-mode integrating; low hold delay rates as a track (reset) and hold module. In the gated amplifier mode, the Model 4850 acts as an SPDT switch which can be commanded to select either one of two inputs and amplifier at arbitrary gains.



MODEL 4850 BLOCK DIAGRAM



SPECIFICATIONS

ACCURACY	±0.1%
INPUT	
Voltage	±10 V
Impedance	Adjustable 2kΩ to 10MΩ
OUTPUT	
Voltage	±10 V
Current	±20 mA
FEEDBACK	
Capacitance	0.001μF to 10μF
Resistance	2kΩ to 10 MΩ
STABILITY	
Average Hold Decay Rate at +25°C	±.06 mV / C (in μF) (max)
at +60°C	±0.5 mV / C (in μF) (max)
Output Switching Jump	±0.05 mV / C (in μF) (max)
Feedthrough Operate FET Switch Open	±1 mV
SWITCHING PERFORMANCE	
Aperture Time	800 nSec
Acquisition Time (Settling to 0.05%)	80 μSec
MODE CONTROL COMPARATORS	
Minimum Logic Level	±0.35 V
Maximum Logic Level	±5 V
Reference Level	±6 V
TEMPERATURE STABILITY	
Operate Mode	±35 μV/°C (max)
Reset Mode	±3 mV/°C (max)
TEMPERATURE RANGE	0°C to +60°C
POWER REQUIREMENT	
Voltage	±15 V
Current	±70 mA
CASE STYLE	T−10
SOCKET	6024 ($4.00)
PRICE (1−9)	$175.00
(10−24)	$166.00

MODEL PPT&H

Track-and-Hold Operator

FEATURES

- High OFF Resistance – $10^{11}\ \Omega$
- Low ON Resistance – 300 Ω
- Fast Aperature Time – < 100 nsec
- Fast Acquisition Time – < 2 μsec

DESCRIPTION

The Model PPT & H Track and Hold Modulator is designed to function with all Teledyne Philbrick Operational Amplifiers and is optimized for use with FET input amplifiers. Performance, especially input current characteristics, will deviate from the specifications depending on the parameters of the amplifier selected. When used with a single operational amplifier, the overall circuit will track an input signal until a logic input is applied that opens the input, holding the output at the same level it had before switching.

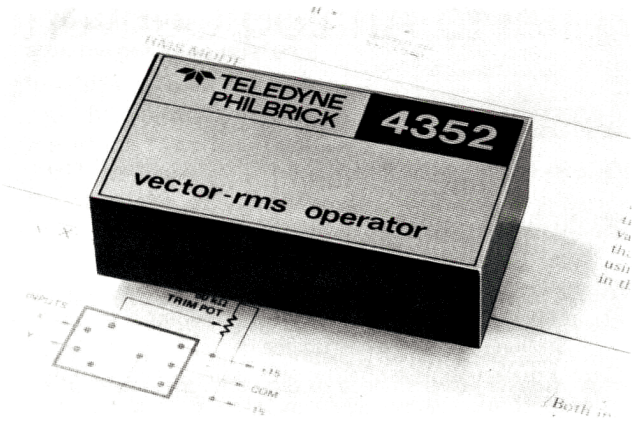
SPECIFICATIONS

INPUT	
Voltage	±10 V
Impedance	ON–300 Ω OFF–$10^{11}\ \Omega$
SWITCHING DELAY GOING INTO HOLD	100 ns(x)* Typical
SWITCHING DELAY GOING OUT OF HOLD	<2 μsec
SWITCHING JUMP GOING INTO HOLD	$\frac{\pm 50\ \text{mV max}}{X}$ *
LOGIC INPUT	±1 V: +1V for track –1V for hold
POWER REQUIREMENT	
Voltage	±15V
Current	±1 mA
CASE STYLE	AS2
SOCKET	US-PP ($3.50)
PRICE	
1–9	$58.00
10–24	$47.50

* $X = \frac{C_{EXT} + 500\ pF}{500\ pF}$

MODEL 4352

Average-RMS-Vector Operator



FEATURES

- Calculating the square root of the sum of the squares of two signals
- Finding RMS values of a signal
- Finding average rectified values of a signal
- Plus, minus or AC input signal
- No external circuits required (trim control optional)

DESCRIPTION

The average–RMS–Vector Operator Model 4352 is a compact, encapsulated unit designed to: find the average value of an input signal, Y; find the RMS value of an input signal, X; or perform the operation $\sqrt{X^2 + Y^2}$ on the input signals X and Y. Averaging and RMS operation is based on instantaneous values of one input signal, with the output appearing as a positive voltage. The operation $\sqrt{X^2 + Y^2}$ is based on instantaneous values of two input signals. The output is a positive voltage, and is the instantaneous value of the function. Also by using two Model 4352 units, the operation $\sqrt{X^2 + Y^2 + Z^2}$ can be obtained. The small size and the multiple functions of which the Model 4352 is capable make it ideally suited for use as a computing element in the laboratory or in manufacturing equipment. Reliable accuracy is provided over a wide range of temperatures and operating conditions.

SPECIFICATIONS

OUTPUT FUNCTION	RMS	Average Rectified	$\sqrt{X^2 + Y^2}$
INPUT			
Voltage			
X	±10 V		±10 V
Y		±10V	±10 V
Current	0.75 mA	1 mA	
OUTPUT			
Voltage	±10V	±10V	±10V
Current	±2 mA	±2 mA	±2 mA
ACCURACY OF FULL SCALE	±3%	±1%	±1%
BANDWIDTH			
–3 dB	20 kHz	20 kHz	1 kHz
TEMPERATURE STABILITY		±0.1%/°C	
TEMPERATURE RANGE		0 to +75°C	
POWER REQUIREMENTS			
Voltage		±15 V	
Current		±30 mA	
CASE STYLE		G1	
SOCKET		NSK-9 ($2.50)	
PRICE			
(1–9)		$138.00	
(10–24)		$132.00	

DATA CONVERSION

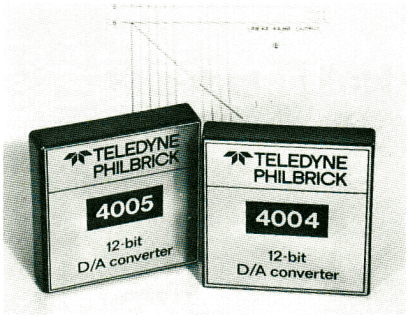
Digital to Analog Converters

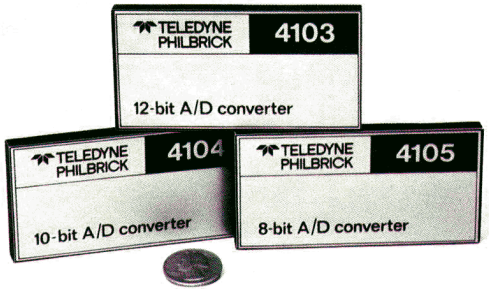
TEST EQUIPMENT • INSTRUMENTATION

PROCESS CONTROL • COMPUTER INTERFACING

DISPLAY SYSTEMS • DATA ACQUISITION

Teledyne Philbrick produces a comprehensive selection of self-contained D/A and A/D Converter modules offering an outstanding range of performance characteristics. Reinforced by the reliability, quality, and experienced applications support you can expect from Teledyne Philbrick, these data conversion "building blocks" are ideally suited to the design of a wide variety of high performance real time, on-line data conversion systems.





HIGH PERFORMANCE

	4010/4011 10-bit Binary		4004/4005 12-bit Binary		4008/4009 12-bit BCD	
	I_{out}	V_{out}	I_{out}	V_{out}	I_{out}	V_{out}
RESOLUTION	10-bits		12-bits		12-bits	
LINEARITY, max	±1/2 LSB		±1/2 LSB		±1/4 LSB (typ)	
OUTPUT	Unipolar or bipolar	Bipolar	Unipolar or bipolar	Bipolar	Unipolar	
Full scale output, ±1%	0 to +2 mA -1 to +1 mA	±10 V	0 to 2 mA -1 to +1 mA	±10 V	0 to +1.25 mA	0 to -10 V
Terminal limits	-1 to +1 V	±5 mA	-1 to +1 V	±5 mA	-1 to +1 V	0 to -5 mA
Zero offset, max	<50 nA @ 70°C	±1/2 LSB	<50 nA @ 70°C	±1/2 LSB	<50 nA @ 70°C	±1/2 LSB
Output impedance	8 kΩ nom.	<0.3Ω	8 kΩ nom.	<0.3Ω	5 kΩ nom.	<0.3Ω
Settling time to within	for 2 mA step	for 10 V step	for 2 mA step	for 10 V step	for 1.25 mA step	for 10 V step
±1/2 LSB of final value	300 nsec	5 μsec	300 nsec	5 μsec	300 nsec	5 μsec
Zero drift vs temp.	3 ppm/°C	20 ppm/°C	3 ppm/°C	20 ppm/°C	3 ppm/°C	20 ppm/°C
Gain vs temp., max	20 ppm/°C		20 ppm/°C		20 ppm/°C	
INPUT						
Logic code	Binary		Binary		BCD (1248)	
Logic input						
TTL loads	<<1 load		<<1 load		<<1 load	
Current	<10 μA		<10 μA		<10 μA	
ANALOG REFERENCE	internal; external capability		internal; external capability		internal; external capability	
POWER REQUIREMENT						
Voltage	±15 V, ±6%		±15 V, ±6%		±15 V, ±6%	
Current	±20 mA	±25 mA (w/load)	±20 mA	±25 mA (w/load)	±20 mA	+20,-25mA(w/load)
Power supply rej, max	±0.002%/%ΔV_s		±0.002%/%ΔV_s		±0.002%/%ΔV_s	
TEMPERATURE RANGE						
Operating	0°C to +70°C		0°C to +70°C		0°C to +70°C	
Storage	-55°C to +125°C		-55°C to +125°C		-55°C to +125°C	
CASE STYLE	E6		E6		E6	
SOCKET	6069 $10.00)		6069 ($10.00)		6069 ($10.00)	
PRICE (1-9)	$110.00	$115.00	$130.00	$135.00	$115.00	$120.00
(10-24)	105.00	110.00	125.00	130.00	110.00	115.00

NOTE

1. 1 TTL load unit equals −1.6 mA max at V_{in} = +0.4 V (LO) and +40 μA max at +2.4 V (HI).

OPTIONAL LOW PROFILE DAC MODULES

Teledyne Philbrick manufactures over 100 DAC circuit modules to meet the wide variety of digital to analog applications. Low profile modules with 8-12-bit resolution and a variety of output capabilities (both voltage and current) can be ordered by applying the diagram below to the standard "high performance" modules described to the left.

Model No. 40xx-xx

- Output
- Number of Bits
- Standard Module

Number of Bits
0 - Standard Module
5 - 8-bit resolution
6 - 9-bit resolution
7 - 11-bit resolution

Output-Current Version
0 - Standard Module
1 - 0 to +2 mA
2 - −1 mA to +1 mA

Output-Voltage Version
0 - Standard Module
3 - 0 to +10 V
4 - 0 to −10V
5 - −10 to +10 V
6 - 0 to +5 V
7 - 0 to −5 V
8 - −5 to +5V
9 - +5 to −5 V

ECONOMY

	4020/4021 8-Bit Binary		4022/4023 10-bit Binary	
	I_{out}	V_{out}	I_{out}	V_{out}
	8-bits		10 -bits	
	±1/2 LSB		±1/2 LSB	
	Unipolar or bipolar		Unipolar or bipolar	
	0 to +2 mA, ±5% -1 to +1 mA, ±5%	0 to -10 V +5 to -5 V	0 to +2 mA, ±5% -1 to +1 mA, ±5%	0 to -10 V +5 to -5 V
	-1 to +1 V	±5 mA	-1 to +1 V	±5 mA
	<50 nA @ 70°C	±1/2 LSB	<50 nA @ 70°C	±1/2 LSB
	8 kΩ nom.	<0.3Ω	8 kΩ nom.	<0.3Ω
	for 2 mA step	for 10 V step	for 2 mA step	for 10 V step
	300 nsec	25 µsec	300 nsec	25 µsec
	4 ppm/°C	40 ppm/°C	4 ppm/°C	40 ppm/°C
	40 ppm/°C		40 ppm/°C	
	Binary		Binary	
	1 load		1 load	
	-1.2 mA		-1.2 mA	
	internal; external capability		internal; external capability	
	±15 V, ±6%		±15 V, ±6%	
	±15 mA	±20 mA (w/load)	±15 mA	±20 mA (w/load)
	±0.05%/%ΔV_s		±0.05%/%ΔV_s	
	0°C to +70°C		0°C to +70°C	
	-55°C to +100°C		-55°C to +100°C	
	E6		E6	
	6069 ($10.00)		6069 ($10.00)	
	(1-99) $19.00	(1-99) $19.00	(1-99) $29.00	(1-99) $29.00

Specifications typical at 25°C with nominal power supply, unless otherwise indicated.

MODELS 4012 & 4013 Binary or BCD 4-bit Expanders

Models 4012 and 4013 4-bit expander modules include a stable precision reference suitable for 16-bit accuracy, and the 4 most significant bits of the 14 or 16-bit DAC. When combined with Philbrick's current output 10 and 12-bit DAC modules, they make possible a series of high performance 14 and 16-bit D/A converters at approximately half the cost of present high resolution converters.

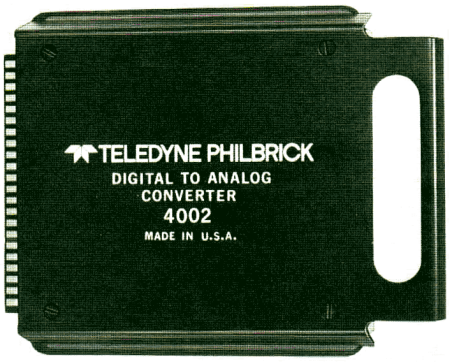
Model 4012 provides a current output that varies from 0 to +4 mA for all "zeros" to all "ones." Model 4013 is a voltage output 4-bit expander. The 4013 includes a high performance FET op amp to provide 0 to -10 volts @ ±5 mA with a 0.01% settling time of 5 µsec.

The 4-bit expanders, like the standard 10 and 12-bit DAC's are packaged in encapsulated Modules. In final operation it is necessary to use a precisely matched series trim resistor (supplied) to normalize the output of the DAC so that it accurately sums with the output of the expander.

Combinations Available	Expander	DAC
14-Bit Binary DAC, Current Output	4012	4010
14-Bit Binary DAC, Voltage Output	4013	4010
16-Bit Binary DAC, Current Output	4012	4004
16-Bit Binary DAC, Voltage Output	4013	4004
16-Bit BCD DAC, Current Output	4012	4008
16-Bit BCD DAC, Voltage Output	4013	4008

	4012	4013
RESOLUTION	4-bits	
LINEARITY, max	Accurate to 16-bits	
OUTPUT	Current	Voltage
Full scale	0 to ±4 mA, ±0.1%	0 to −10V, ±0.1%
Terminal limits	±1/2 V	±15 mA
Output impedance	5 kΩ	<0.5 Ω
Settling time to within ±0.01% of final value, max	300 nsec	5 µsec
Zero drift vs temp., max	-0.5 nA; 2x/10°C	±7 ppm/°C
Gain vs temp., max	±7 ppm/°C	
INPUT		
Logic code	Binary or BCD	
ANALOG REFERENCE	Built-in; with external capability	
POWER REQUIREMENTS		
Voltage	±15 V	
Current	±20 mA	±35 mA
Power supply rej., max	±0.002%/%ΔV_s	
TEMPERATURE RANGE		
Operating (Rated Specs)	+15°C to +35°C	
Storage	-55°C to +100°C	
CASE STYLE	E6	
SOCKET	6069 ($10.00)	

MODEL 4002
Precision 14-bit "Deglitched" DAC



Model 4002 is designed to meet the need for a fast digital to analog converter. Unique solid state circuitry makes the 4002 ideally suited to applications in test and display systems by offering a controlled monotonic transition between levels combined with freedom from glitches and overshoots (less than ±5 mV). In addition, the 4002 features magnitude and sign coding circuitry to offer superior accuracy and stability around zero.

The digital inputs are DTL and TTL compatible and an input storage register allows information to be strobed in. Mechanically, the unit is a completely self-contained, rugged aluminum plug-in case providing the user with gain and offset adjustments. Other features include an excellent PSRR, low drift, and fast settling time.

RESOLUTION . . . . . 14-bits, incl. sign
LINEARITY, max . . . . . ±1/2 LSB
OUTPUT (Full scale) . . . . . ±10 V/±5 mA
Glitches . . . . . ±3 mV peak
Gain vs temp., max . . . . . ±7 ppm/°C
Zero drift vs temp., max . ±30 μV/°C
Settling time . . . . . <20 μsec/10 V
2 μsec/LSB step
LOGIC INPUT . . . . . DTL/TTL Comp
Logic Code . . . . . Magnitude and sign; binary
Sink Current . . . . . 2 TTL loads
POWER REQUIREMENTS ±15 V/±36 mA
+5 V/205 mA
PSRR vs +15 or -15 V
Gain, max . . . . . ±0.05%/V
Offset, max . . . . . ±0.5 mV/V
TEMPERATURE RANGE
Operating . . . . . +15 to +45°C
Storage . . . . . -25 to +100°C
CASE STYLE E8
PRICE (1-9) $545.00
(10-24) 525.00

MODELS 4015, 4017 & 4019
Fast Settling "Deglitched" DAC'S

Models 4015, 4017, and 4019 are ideally suited to high speed display system applications where a DAC must have good accuracy and resolution; slew and settle quickly; exhibit a high degree of monotonicity; extremely low noise; and no "glitches." The three versions offer 12-bit, 13-bit, and 14-bit resolution, respectively; and ±1/2 LSB accuracy. Small signal settling time of 200 nsec to ±2 mV of final value allows update rates of 2.5 to 3 MHz in the vector display mode.

The extremely low average transient noise and the virtual absence of glitches allow the units to be used for display systems which require continuous positioning waveforms.

Another feature of these DAC's, important in many waveform generating applications, is the symmetry and uniformity of the output step of the waveform. Because the switching characteristics of each bit are identical to every other bit, an output waveform may be filtered to produce a continuous function without discontinuities due to switching transients.

RESOLUTION (4015) 12-bits
(4017) 13-bits
(4019) 14-bits
LINEARITY (max) . . . . . ±1/2 LSB
OUTPUT
Full scale . . . . . ±10 V, adj.
Short circuit current . . . . 100 mA
Zero offset . . . . . Adj. to zero
Small signal rise time . . . 70 nsec
Small signal settling time . 200 nsec to 2 mV of F.V. for 100 mV step
Large signal settling time 5 μsec to 0.01% for 10 V step
Overshoot . . . . . 10% for signals <1 V
Glitches, max . . . . . ±20 mV
Through put delay . . . . . 200 nsec
Gain vs. temp. . . . . ±20 ppm/°C
Zero drift vs. temp. . . . . ±10 ppm/°C
INPUT LOGIC CODE . . . . Binary or 2's complement
POWER REQUIREMENT . . +5 V/250 mA
±15 V/150 mA
TEMPERATURE RANGE
Operating . . . . . 0 to +70°C
Storage . . . . . -25 to +125°C
CASE STYLE E8

MODELS 4014, 4016, & 4018
High Speed Current Binary DAC'S

Models 4014, 4016, and 4018 are high speed current DAC modules that settle in less than 100 nsec directly into an op amp summing point. Resolution is 12-bits, 13-bits, and 14-bits respectively. Since it is a true current output, the output impedance is high (the output collector impedance) allowing an output amplifier to operate at unity gain to minimize noise and temperature drift effects. Proprietary high speed beta-equalization circuitry is used throughout the module to achieve up to 14-bit accuracy at very high speeds.

Most current DAC designs happen to have rather high values of output capacitance, which is not generally specified by most manufacturers. Output capacitance tends to limit output response when driving finite load resistance (the lower the RC product, the faster the output response), and for this reason the 4016 output capacitance has been kept to a typical value of 5 to 7 pF.

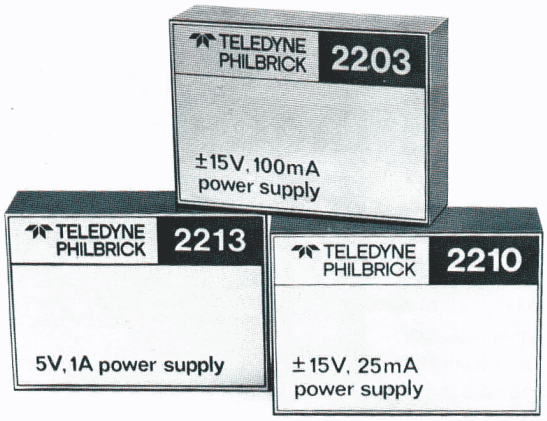
RESOLUTION (4014) 12-bits
(4016 . . . . 13-bits
(4018) 14-bits
LINEARITY, max . . . . . ±1/2 LSB
OUTPUT, full scale . . . . . 0 to +16 mA, ±8 mA
Terminal limits . . . . . ±1/2 V
Zero offset . . . . . -0.5 nA
Large signal settling time . 100 nsec to 0.01% for FS step
Gain vs. temp., max . . . . ±20 ppm/°C
Zero drift vs. temp. max. ±10 ppm/°C
INPUT LOGIC CODE . . . . . Binary
Logic input current . . . . <100 μA
TTL Loads . . . . . ≪1 Load
POWER REQUIREMENT . . ±15 V/150 mA
TEMPERATURE RANGE
Operating . . . . . 0 to +70°C
Storage . . . . . -25 to +85°C
CASE STYLE E10
SOCKET 6121 ($15.00)

Analog to Digital Converters

	SUCCESSIVE APPROXIMATION		DUAL SLOPE		TRACKING
	4103 (12-bit) **4104 (10-bit)** **4105 (8-bit)** **Binary**	**4106 (12-bit)** **4107 (10-bit)** **4108 (8-bit)** **Binary**	**4109** **12-bit** **Binary**	**4111** **12-bit** **BCD**	**4110** **8-bit** **Binary**
RESOLUTION	(4103) 12-bits (4104) 10-bits (4105) 8-bits	(4106) 12-bits (4107) 10-bits (4108) 8-bits	12-bits		8-bits
LINEARITY, max	±1/2 LSB		±1/2 LSB		
QUANTIZING ERROR, max	±1/2 LSB		±1 LSB Includes Hysteresis		
ZERO ERROR (offset), max	±1/2 LSB External Adj. to Zero		±5 mV External Adj. to Zero		
GAIN ERROR (Scale factor), max	±2%, ±0.01% Stable		±2%, ±0.02% Stable		±0.1%
GAIN vs TEMPERATURE, max	±20 ppm/°C		±20 ppm/°C		±100 ppm/°C
ZERO DRIFT vs TEMP. max	±5 ppm/°C		±1 ppm/°C		±20 μV/°C
CONVERSION TIME	(4103) <30 μsec (4104) <20 μsec (4105) <15 μsec	(4106) <10 μsec (4107) <6 μsec (4108) <5 μsec	See note 5		<25 μsec
CONVERSION RATE	(4103) >33 kHz (4104) >50 kHz (4105) >65 kHz	(4106) >100 kHz (4107) >170 kHz (4108) >200 kHz	– –		<40 kHz
POWER SUPPLY REJECTION	±0.001%/%ΔV_s		±0.005%/%ΔV_s		±0.05%/%ΔV_s
STEPPING RATE – per LSB	– –		– –		10 MHz
INPUT					
Input Voltage Range	0 to -10 V or +5 V to -5 V		(4109) (4111) 0 to -10 V (410910) (411110) 0 to +10 V		±5 V or 0 to -10 V ±10 or ±20 V (opt.)
Terminal Limits	±20 V		– –		±25 V
Input Impedance	2 kΩ		100 kΩ		4 kΩ
Input Offset Current	±200 μA		<1 μA		150 μA
Convert Command Signal	See Note 3		See Note 8		See Note 10
Input Data Rate (sine wave)	– –		– –		3 kHz
OUTPUT	Binary or Offset Binary		(4109) Binary (4111) BCD		Binary
LOGIC OUTPUT					
TTL Loads	See Note 4		8 TTL		
STATUS SIGNAL	See Note 7		See Note 9		– –
CLOCK	Internal		Internal		
Duty Cycle	Positive going; 50 nsec min, 500 nsec max		– –		
Rate	(4103) >390 kHz (4104) >600 kHz (4105) >780 kHz	(4106) >1.2 MHz (4107) >2.0 MHz (4108) >2.4 MHz	– –		
POWER REQUIREMENTS					
Voltage	±15 V, ±0.5V and +5 V, ±0.5 V		±15 V and +5 V		
Current	±50 mA +200 mA		±30 mA +150 mA		
TEMPERATURE RANGE					
Operating	0°C to +70°C				
Storage	-55°C to +100°C				
CASE STYLE	E9		E7		
SOCKET	6121 ($15.00)		6122 ($12.00)		
PRICE (1-9)	(4103) $275.00 (4104) 205.00 (4105) 185.00	(4106) $365.00 (4107) 295.00 (4108) 275.00	(4109/10) $98.00 (4111/10) 98.00		$85.00
(10-24)	(4103) $265.00 (4104) 196.00 (4105) 177.00	(4106) $350.00 (4107) 282.00 (4108) 263.00	(4109/10) $94.00 (4111/10) 94.00		$82.00

NOTES:
1. All specifications are typical at 25°C, nominal power supply, unless otherwise indicated.
2. TTL load unit equals −1.6 mA max at V_{in} = +0.4 V (LO) and +40 μA max at +2.4 V (HI).
3. Negative going pulse, 50 nsec min width - max width 500 nsec. (Reset at '0' conversion, start at '0' to '1' transition.)
4. Serial (non-return to Zero-MSB first) and parallel output standard. 4 TTL loads for parallel and 10 TTL loads for serial.
5. Conversion time for BCD 100% over range is 2.5 msec max, for Binary 6 msec max.
6. All control inputs, outputs, and data output lines are compatible with standard TTL/DTL logic levels. Logic State Switch '0' is <+0.8V; Logic State Switch '1' is >+2.0V.
7. Complete Signal – Logic '1' at the end of conversion.
8. Reset/Start Signal – Positive going pulse 100 nsec min. resets on positive transition, starts conversion on negative transition.
9. $\overline{\text{Complete}}$ Signal – Logic '1' during conversion.
10. Reset Signal – Negative pulse from Logic '1' 50 nsec min. Logic '0' resets converter to mid-scale, Logic '1' initiates conversion.

POWER SUPPLIES & REGULATORS



FEATURES

- Small Size (Encapsulated Modules)
- Short Circuit Protection
- Excellent Line and Load Regulation
- 25 mA to 1000 mA Output Current
- No RFI Generated or Transmitted
- Versatile and Trimmable (Models 2203/2204)
- Custom Modifications

Reliable power is the foundation of analog or logic systems. Teledyne Philbrick designs and manufactures a comprehensive line of Power Supplies for logic networks and circuit modules such as operational amplifiers, digital-to-analog and analog-to-digital converters, and nonlinear circuit modules.

	HIGH PERFORMANCE				NEW LOW COST		
	2203	**2204**	**2208**	**2209**	**2210**	**2211**	**2212**
Output							
Voltage (±1%)	±15 V	±15 V	±15 V	±15 V	±15 V	±15 V	±15 V
Current, operating	±100 mA	±50 mA	±100 mA	±50 mA	±25 mA	±50 mA	±100 mA
Current, short circuit	±60 mA	±30 mA	±60 mA	±30 mA	– –	– –	– –
Regulation							
Line, max (105-125 Vac)	±0.03%	±0.03%	±0.03%	±0.03%	±0.2%	±0.1%	±0.05%
Load, max (0-100%)	±0.03%	±0.015%	±0.03%	±0.015%	±0.2%	±0.1%	±0.1%
Temperature coefficient, max	±0.01%/°C	±0.01%/°C	±0.01%/°C	±0.01%/°C	±0.02%/°C	±0.015%/°C	±0.015%/°C
Warm-up drift	45 mV	35 mV	45 mV	35 mV	30 mV	35 mV	45 mV
Ripple and noise, max	1 mV rms	1 mV rms	1 mV rms	1 mV rms	1 mV rms	1 mV rms	1 mV rms
Impedance @ 10 kHz	0.2 Ω	0.2 Ω	0.2 Ω	0.2 Ω	0.2 Ω	0.2 Ω	0.2 Ω
Temperature Range							
Operating (°C)	-25 to +85	-25 to +85	-25 to +85	-25 to +85	0 to +70	0 to +70	0 to +70
Storage (°C)	-35 to +125	-35 to +125	-35 to +125	-35 to +125	-25 to +85	-25 to +85	-25 to +85
Input							
Voltage (±10%)	115/230 Vac	115/230 Vac	115 Vac	115 Vac	115 Vac	115 Vac	115 Vac
Isolation	50 MΩ	50 MΩ	50 MΩ	50 MΩ	50 MΩ	50 MΩ	50 MΩ
Frequency	50 to 400 Hz	50 to 400 Hz	50 to 400 Hz	50 to 400 Hz	50 to 400 Hz	50 to 400 Hz	50 to 400 Hz
Case Style	C1	C1	C3	C3	C4	C4	C3
Mating Socket	6036 ($5.00)	6036 ($5.00)	6036 ($5.00)	6036 ($5.00)	6036 ($5.00)	6036 ($5.00)	6036 ($5.00)
Options *	– –	– –	21	21	21	21	21
Price							
1-9 Quantity	$57.00	$46.00	$57.00	$46.00	$23.00	$39.00	$49.00
10-24 Quantity	$55.00	$44.00	$55.00	$44.00	$22.00	$38.00	$47.00

* Options Available

For 230 Vac, 50-400 Hz input, add the suffix "21" to the model number. No additional charge

All power supplies are complete and self-contained. No external transformers or filters are required for stable, accurate operation. This one unit construction is easier to use, and reduces component and assembly costs of the equipment being manufactured. For added mechanical strength the encapsulated supplies can be fastened to a P.C. Board or in optional mating sockets by supplied hold-down nuts.

PROTECTION

All Teledyne Philbrick power supplies are protected against overheating from direct short circuits to ground. The dual supplies will track each other so that a short on one output will automatically reduce the other output to prevent damage to the load circuitry.

	MICROLOGIC		HIGH POWER	
	2206	**2213**	**2207**	**2214**
	+5 V	+5 V	±15 V	±15 V
	+500 mA	+1000 mA	±500 mA	±1000 mA
	+150 mA	– –	±150 mA	– –
	±0.1%	±0.05%	±0.02%	±0.02%
	±0.15%	±0.1%	±0.05%	±0.05%
	±0.01%/°C	±0.02%/°C	±0.03%/°C	±0.03%/°C
	15 mV	25 mV	25 mV	25 mV
	2 mV p-p	1 mV rms	5 mV p-p	5 mV p-p
	0.1 Ω	0.2 Ω	0.2 Ω	0.2 Ω
	-25 to +85	-25 to +70	-20 to +50	-20 to +50
	-35 to +125	-55 to +85	-40 to +75	-40 to +75
	115/230 Vac	115 Vac	115 Vac	115 Vac
	50 MΩ	50 MΩ	100 MΩ	100 MΩ
	50 to 400 Hz	50 to 400 Hz	50 to 400 Hz	50 to 400 Hz
	C1	C5	C2	C2
	6036 ($5.00)	6036 ($5.00)	– –	– –
	– –	21	21	21
	$48.00	$67.00	$98.00	
	$46.00	$64.00	$95.00	

Characteristics typical at 25°C with nominal line voltage, unless otherwise indicated

MODEL 2101 DUAL VOLTAGE REGULATOR

FEATURES

- Regulation ±0.01% for line and load.
- Automatic "foldback" current limiting for overload protection. Short circuit current typically 10 mA
- 100 mA outputs for a wide range of loading requirements
- ±50 ppm/°C typical temperature coefficient over operating range −55°C to +85°C
- Wide input range of 20-40 Volts permits use with poorly regulated and filtered supplies
- Voltage track when overloaded prevents damage to load circuits from voltage

DESCRIPTION

Model 2101 Dual Regulator is a precision three-wire supply designed primarily to provide well regulated voltages for operational amplifier circuits. Output regulation is within 0.01% for all loads and input voltages within the ratings of the Dual Regulator, even under widely varying ambient temperature.

Applications include use as a general purpose regulator for operational amplifier supply voltages; as a precision regulator in systems when higher voltage is available; as a small-size, low weight, low cost unit in manufactured equipment. In systems needing precisely regulated voltages at several separate locations, use a Model 2101 at each location.

Rugged epoxy-encapsulated construction, plus small size and weight, complement the close tolerance electrical specifications for outstanding applicability to a wide range of uses in original equipment.

SPECIFICATIONS

OUTPUT RATING . . . . . ±15 V/100 mA

STABILITY CLASS 0.02%

OUTPUT VOLTAGE

- Factory adjusted to within (Max) . . . . . ±200 mV
- Range . . . . . ±14 to ±15.5 V
- Vs. Load (0 to 100%), Max . . . . . 1.5 mV
- recovery time, Typ . . . . . 50 μsec
- Vs. Line (±20 to ±40 V dc), Max . . . . . 1.5 mV
- Vs. Temperature, Typ . . . . . 1 mV/°C
- (over operating range), Max . . . . . 0.2 V
- Noise and Ripple, p-p, Max . . . . . 1.5 mV

OUTPUT CURRENT

- Under nominal conditions, Typ. . . . . 120 mA
- Worst case ($\triangle V_{in}$ & $\triangle$Temp), Gtd. Min . . 100 mA

INPUT VOLTAGE

- Nominal . . . . . 25 V dc
- Range Typ. . . . . ±20 to ±40 V dc

TEMPERATURE RANGE (in °C)

- Operating . . . . . −55 to +85
- Storage . . . . . −55 to +125

CASE STYLE G3

SOCKET . . . . . NSK−13 ($2.00)

PRICE

- 1–9 . . . . . $50.00
- 10–24 . . . . . $47.00

TESTERS

Models 5104 and 5107 Automatic Operational Amplifier Testers

Features

- Automatic or semi-automatic operation
- Tests up to 16 parameters
- Slew rate Testing (5107 only)
- Synchronous Detection Minimizes Noise and Drift
- Oscillation Detection
- Plug-in construction for ease of servicing
- GO/NO testing of all parameters
- Comparator testing
- Manual, internal or remote programming

DESCRIPTION

Models 5104 and 5107 Automatic Operational Amplifier Testers offer rapid automatic or semi-automatic testing of up to 16 op amp parameters. In the automatic mode Model 5104 performs 14 tests in 2.8 seconds, and the Model 5107 performs 16 tests in 3.2 seconds on a GO/NO basis using easily programmable test limits. The semi-automatic mode allows test selection by individual push-buttons for a detailed evaluation of amplifier performance.

Models 5104 and 5107 are electronically identical with the exception that Model 5107 offers the additional feature of plus and minus slew rate testing. Both testers use the synchronous demodulation technique to provide excellent signal-to-noise ratio and low drift for consistently accurate measurements.

A variety of inexpensive test sockets are available to accommodate most discrete and microcircuit op amps, as well as the 710 and 711 type comparators. Test sockets for special amplifiers and comparators can be designed to meet nearly any user requirement.

In the automatic mode the tester scans through the selected tests comparing to a preset GO/NO limit. A GO condition advances the scanner to the next test. If all tests are passed, a front panel GO indication is given and the scanner resets for the next testing sequence. A NO condition stops the scanner on the failed test, displays the parameter on the front panel meter and illuminates the front panel NO indicator. At this point, the remaining parameters may be tested or the scanner reset for the next device.

In the semi-automatic mode, any individual test may be selected by depressing the corresponding front panel push-button. The parameter is displayed in engineering units (mV, nA, dB, etc.) on the easy-to-read 5" taut-band meter with separate polarity indication. GO/NO indications are also given and may be used for reference.

Test conditions, supply voltages, and meter scaling may be selected by front panel controls or programmed internally with two plug-in cards for both automatic and semi-automatic operation. This enables the user to preprogram all test conditions and scaling on one set of cards for a

TEST	CONDITION	RANGES	ACCURACY
Quiescent Supply Currents – $\pm I_{cc}$	Unity gain follower with no signal	0 – ±3 mA, ±30 mA	±5%
Input Offset Voltage – E_{os}	Internal Source Z ≈ 50Ω	0 – ±3 mV, ±30 mV	±5%
Input Bias Currents – $\pm I_{BIAS}$	V_{out} and $V_{cm} \leqslant \lvert 300 \rvert$ mV	0 – ±0.3, 3.0, 30, 300 or 3000 nA	±5%
Input Offset Current I_{os}	Same as I_{BIAS}	Same as I_{BIAS}	Same as I_{BIAS}
Open Loop Gain	Output swing between ±4 and ±20 volts Load between 330Ω and 20K (See Front Panel Controls)	60 – 120 dB Pos. or Neg. Slope Indicated	±2 dB
Maximum Output Swing – $\pm E_{out}$	AUT is driven to + and – limits	0 – ±30 volts	±5% or 100 mV
Common Mode Rejection Ratio–CMRR	Test signal between ±2 and ±10 volts (See Front Panel Controls)	60 – 120 dB Pos. or Neg. Slope Indicated	60 – 80 dB ±1 dB 80 – 95 dB ±2 dB 95 – 110 dB ±3 dB
Common Mode Voltage $\pm E_{cm}$	AUT is driven to level where CMRR ≈ 40 dB	0 – ±30 volts	±5% or 100 mV
Power Supply Rejection Ratio–±PSRR	Each supply modulated with ±0.5 volts	60 – 120 dB	60 – 110 ± 1 dB
± Slew Rate (5107 only)	Amplifier connected as inverter with programmable E_o and slew interval.	±0.1 to ±100 V/μsec	±10% (to10 V/μsec)
Oscillation Detect	Detects oscillation over 150 mV between 10 kHz and 10 MHz		

particular op amp type, minimizing operator time and error in changing from one device type to another. At the same time, front panel controls allow complete flexibility in the semi-automatic mode for evaluation of parameter changes vs. test conditions changes, such as output swing vs. load resistance, and for quickly setting up any combination of scaling, supply voltage, and test condition.

A third program card selects the tests to be performed in the automatic mode, and also provides multiturn potentiometers for setting the GO/NO limits for each test. These pots may be replaced with fixed resistors to set the GO/NO limits for an individual device, again allowing rapid change from one device type to another.

All necessary inputs for interfacing with automatic handlers, classifiers, data acquisition systems, etc. are provided on rear panel connectors. Modular construction is employed throughout the Models 5104 and 5107 for ease of maintenance and service.

FRONT PANEL INDICATORS

METER DISPLAY gives readout of test parameter in engineering units. Meter is taut-band individually calibrated 0–3 for voltage/current and 60–120 dB for ratio measurements. Model 5107 has 0.1 to 100V/μsec scale for slew rate. Meter signal for these ranges is available as 0 to +5 volt signal at rear connector.

POLARITY INDICATOR lights to indicate polarity of voltage/current measurements and slope of ratios. Polarity is available at rear connector.

OSC DET lights to indicate oscillations over 150 mV between 10 kHz and 10 MHz.

GO/NO indicators light to indicate AUT condition compared to preset limit. Rear outputs also provide GO/NO information.

PROGRAM CARDS

GO/NO LEVEL PROGRAM CARD has potentiometers for programming test Go levels. Go level is programmed by depressing Go level verify pushbutton and adjusting potentiometer to desired limit on front panel meter. Switches on program card can be set to omit certain tests, optimizing test time.

POWER SUPPLY PROGRAM CARD has two potentiometers to permit continuous adjustment of positive and negative supplies, from ±4 to ±24V.

METER SCALING PROGRAM CARD internally selects the desired meter range for $\pm I_{CC}$, E_{OS}, I_{BIAS}, and I_{OS}.

FRONT PANEL CONTROLS

METER SCALES are provided for independent selection of $\pm I_{CC}$, E_{OS}, I_{BIAS}, and I_{OS}. All selectors have a P (program) mode for transfer of control to internal or remote program.

POWER SUPPLY CONTROLS permit independent control of ± power supplies. Switch selectable voltages are 6, 12, 15, 18 and 24 volts. The P (program) switch position transfers selection to internal card (continuously variable) or remote program. Power supplies deliver 100 mA at 15 volts with short circuit protection.

TEST CONDITION SELECTORS determine Output Swing for gain test (±4, 8, 10, 14, 18, and 20 volts), Common Mode Test Voltages for CMRR test (±2, 4, 5, 7 and 10 volts) and Load for AUT (20k, 10k, 5k, 3.3k, 2k, 1k, 500Ω and 300Ω). All test condition selectors have P (program) mode for internal or external programming of test conditions.

MANUAL TEST SELECT/INDICATOR PUSHBUTTONS allow selection of tests. External Test pushbutton set AUT at unity gain with input and output available at rear connector. Two blank pushbuttons provide for expansion capabilities. Scan pushbutton sets instrument for automatic operation.

AUTO-SCAN INITIATE/INDICATE (TEST) SWITCH applies power to AUT and initiates automatic scan when in scan mode. Light indicates power on to AUT.

VERIFY PUSHBUTTONS confirm limit level and power supply voltages on front panel meter as well as provide ease of programming for limit levels.

MODEL 5104 & 5107 TEST SOCKETS

6041	709 Family in DIP (carrier)	$ 50.00
6044	9-pin Q pkg., 2.5 k Trim	50.00
6045	Blank with 5′ Cable for Auto Handler	50.00
6050	Blank	25.00
6052	Low I_{BIAS} for 7 & 9-pin Q pkg.	750.00
6055	709 Family in TO-99	50.00
6056	Dual 709 in DIP (carrier)	50.00
6057	9-pin Q pkg., 1 k Trim	50.00
6058	9-pin Q pkg., 50 k Trim	50.00
6059	9-pin Q pkg., 1 M Trim	50.00
6060	709 Family in 14 pin Flatpack	50.00
6061	For Philbrick Q25AH	50.00
6062	7-pin Q pkg., 2.5 k Trim	50.00
6063	7-pin Q pkg., 50 k Trim	50.00
6064	709 Family, 14 pin DIP	50.00
6065	Philbrick E1 pkg., 100 k Trim	50.00
6066	710 Comparator, TO-99 and DIP	750.00
6076	LM101, LM107, and 741 Types, TO-99 & DIP	100.00
6113	711 Dual Comparator, TO-99 & DIP	750.00
6114	709 Family, TO-99 & DIP	100.00

MODEL 5104 & 5107 PROGRAM BOARDS

6038	$\pm V_{CC}$, E_{OUT}, and E_{CM}	$ 15.00
6039	Meter Scale; I_{CC}, I_{BIAS}, I_{OS}, and E_{OS}	15.00
6040	GO/NO for each test, 17 pots	75.00
6047	GO/NO Blank each test, fixed Resistors	15.00
6067	5107 Slew Rate Buffer	10.00
6068	5107 Slew Rate Limit	10.00
6070	5107 Slew Rate Buffer (blank)	5.00
6071	5107 Slew Rate Limit (blank)	5.00

ORDERING INFORMATION

Teledyne Philbrick Model 5104 or 5107 Automatic Op Amp Testers include:

- 6050 Blank Test Socket
- 6051 Extender Card
- 6038 Test Condition Program Board
- 6039 Meter Scaling Program Board
- 6040 GO/NO Program Board
- Mating connectors for interface

Units operate on 115/230, 50-60 Hz.

Model 5104:	$5,500.00 (115 V)
Model 510401:	5,500.00 (230 V)
Model 5107:	6,000.00 (115 V)
Model 510701:	6,000.00 (230 V)

Test Socket for any standard Op Amp.

(specify type).

Model 5102 Operational Amplifier Tester

DESCRIPTION

Philbrick Model 5102 Operational Amplifier Tester is a semi-automatic test instrument designed to test dynamic and static characteristics of integrated circuit and discrete component operational amplifiers. Prime applications are for low volume quality control and production testing and engineering evaluation. For high volume testing, the automatic op amp testers, models 5104 and 5107, are recommended.

The Model 5102's unique synchronous detection system permits low-frequency measurements with a minimum of noise, flutter, and drift. All tests are performed with the amplifier in a closed-loop mode of operation with the amplifier output voltage automatically zeroed for offset.

DC TEST FEATURES

OSC DET
: The OSC DET test triggers a red light in case of oscillation which exceeds 10 mV peak, 100 Hz to 10 MHz with the amplifier connected for 100% feedback. Units failing this test will be unstable in most operational circuit applications.

E_{OS}
: Equivalent input offset voltage is determined on a DC basis using conventional analog techniques. The measurement features automatic output zeroing, for fast, accurate reading.

$\pm I_{BIAS}$
: Measured at "+" (non-inverting) and "–" (inverting) input terminals separately, by turning the input/polarity selector to the corresponding positions.

I_{OS}
: This measurement shows the algebraic difference of the $\pm I_{BIAS}$ measurements.

$\pm I_{CC}$
: An indication of Op-Amp efficiency. Current is measured under no-signal condition, with a direct reading of current from the positive or negative supply as determined by the input/polarity selector.

DYNAMIC TEST FEATURES

The following parameters are determined dynamically through the use of low frequency square waves and feedback techniques. Synchronous detection allows accurate readings at low signal levels, with minimum noise.

GAIN
: Measured in a stable closed-loop mode with the amplifier under test operating at full output under load, closely simulating the probable conditions of operation. In addition, the AC measuring techniques for gain measurement eliminate noise, flutter, drift and offset voltage error which would be present with DC measuring methods. The read-out is in dB and Volts/Volt.

CMRR
: Computes common mode rejection by varying the common voltage while simultaneously observing the equivalent input offset voltage generated. As the same read-out and detection scheme is used as for the other dynamic tests, this parameter is displayed both logarithmically and in dB.

$\pm E_{OUT}$
: The test for peak output voltage swing is completely automatic. Maximum output voltages of either polarity are read directly from the meter.

$\pm E_{CM}$
: Determines the common mode voltage required to drive the amplifier under test into its non-linear region. No calibration or operator decisions required to obtain the measurement.

±PSRR
: The test is based on observing the change in input offset voltage as a function of change in power supply voltage. An immediate reading is given by setting the TEST SELECT switch to PSRR.

OTHER FEATURES

Program Card – Standard test card (Model 6007) programs the following test conditions:
- Supply voltages ± 15 volts
- CMRR Test Signal ± 5 volts
- Output for Gain Test ± 10 volts

Other cards available as accessories

Power Supply
- Internal, ± 100 mA at 15 volts

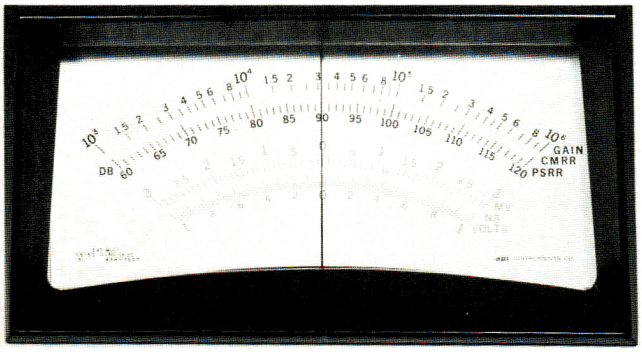
Power Requirements
- 115 or 230 volts (specify) 50/60 Hz, 10 watts

Controls
- Test Selector – Six position selector – DC Test, Gain, CMRR $\pm E_{OUT}$, $\pm E_{CM}$, ±PSRR
- DC Test – Five position selector – Osc. Det., $\pm E_{OS}$, $\pm I_{BIAS}$, I_{OS}, $\pm I_{CC}$
- Meter Sensitivity (I_{OS}, $\pm I_{BIAS}$, and E_{OS}) – 10, 30, 100 300 and 1000 mV/nA full scale
- Input/Polarity Selector
- Load Selector – Nine position switch – 330Ω, 500Ω, 1k, 2k, 3.3k, 5k, 10k, 20k, Ext. (Operational for Gain and $\pm E_{OUT}$)
- Op-Amp Power Switch/Indicator
- Power Switch/Indicator

Test Sockets —Two Front Panel plug-in test sockets supplied
6005 (709/741 family), with frequency compensation as recommended by manufacturer for unity gain
6008 for modular amplifiers, standard 7-pin configuration, no frequency compensation, trim potentiometer (50,000 ohms) connected as rheostat from $+V_{cc}$ to TRIM pin
Other test sockets available as accessories as listed.

SPECIFICATIONS

Gain	60 to 120 dB 60 to 115 dB, ± 1 dB
Common Mode Rejection Ratio	60 to 120 dB 60 to 80 dB, ± 1 dB 80 to 90 dB, ± 2 dB 90 to 110 dB, ± 3 dB
Power Supply Rejection Ratio	60 to 120 dB 60 to 110 dB, ± 1 dB
Maximum Output Swing	0 to ± 30 V, ± 3%, 30 V full scale
Common Mode Range	0 to ± 30 V, ± 3%, 30 V full scale
Input Offset Voltage	0 to ± 1,000 mV, ± 3%, 10, 30, 100, 300 1,000 mV full scale
Input Bias & Offset Curr.	0 to ± 1,000 nA, ± 3%, 10, 30, 100, 300, 1,000 nA full scale
Quiescent Supply Current	0 to ± 30 mA, ± 3%, 30 mA full scale
Oscillation Detector	Detects oscillations of 10 mV peak, 100 Hz to 10 MHz
Output Load	Operational for GAIN and ± E_o Internal: 8 values, 330Ω to 20 kΩ External: to 20 kΩ
Power Supply	Each supply internally programmable from 4 to 24 VDC, short circuit proof, ± 100 mA at ± 15 VDC
Power Required	115 or 230 VAC (specify) 50 to 60 Hz
Power Consumption	Approximately 10 Watts
Dimensions and Weight	12½"L x 15"W x 11"H, 11 lbs.



TEST SOCKETS FOR MODEL 5102

MODEL	AMPLIFIER/SOCKET TYPES	PRICE
6005*	709/741 Family in TO-99 Package	$ 30.00
6008*	7-pin Q package	45.00
6010	MC1533 in TO-99 type package	30.00
6011	Teledyne Semiconduc. 809C in TO-99	30.00
6012	LM 101 in TO-99	30.00
6014	Blank Socket	15.00
6015	Philbrick 8-pin E1 package	45.00
6026	7-pin Q package (High Frequency, i.e., 1011)	45.00
6028	MC1439G in TO-99	30.00
6030	MC1437P (Dual 709) in 14-pin DIP	45.00
6031**	Low Current Socket for 7-pin Q	100.00
6032	MC1433P in 14-pin DIP	45.00
6033	9-pin Q package	30.00
6034	709/741 Family in 14-pin DIP	30.00
6046	Calibration Fixture	100.00

Other sockets supplied on request

*Supplied with 5102
**Model 6031 extends the range of the 5102 to the pico amp scales for FET input device testing. The 6031 divides each I_B range by a factor of 1000 with an accuracy of ± 10% of reading or ± 3 pA, whichever is greater, with resolution down to ± 10 pA.

PROGRAM CARDS FOR MODEL 5102

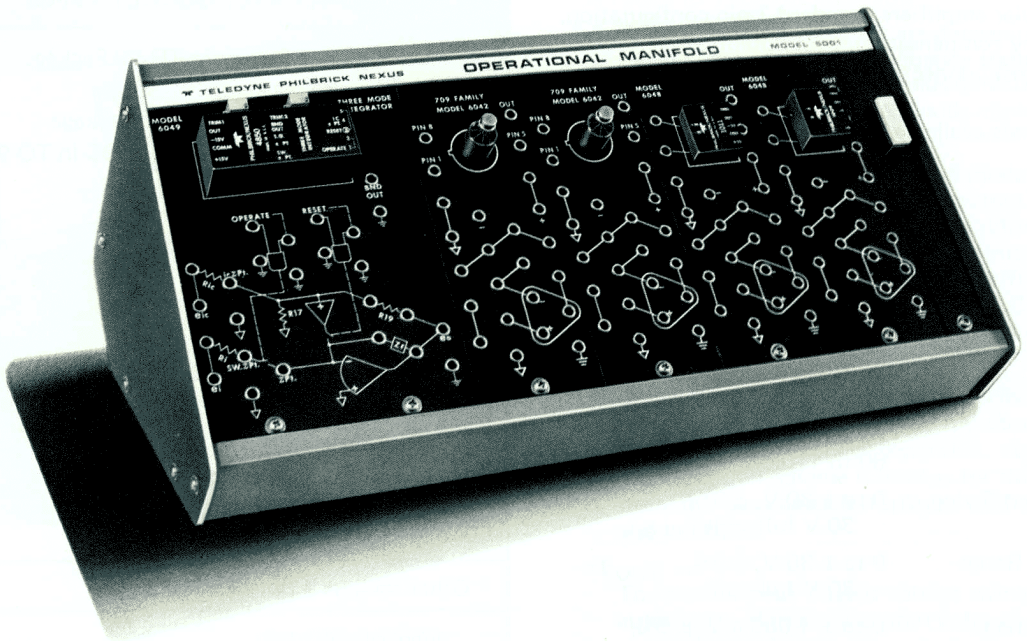
MODEL ± V_{cc}	OUTPUT SWING FOR GAIN TEST	CMRR TEST LEVEL	PRICE
6007* ± 15 VDC	± 10 volts	± 5 volts	$ 25.
6016 ± 6	± 4	± 3	25.
6017 ± 12	± 8	± 5	25.
6018 ± 18	± 14	± 6	25.
6019 +12V,–6V	± 5	± 1/2	25.
6020 ± 24	± 20	± 6	25.
6021 Blank Card			5.
6022 ± 9	± 6	± 4	25.

*Supplied with 5102

ORDERING INFORMATION

Model 5102 Operational Amplifier Tester $1,995.00
Accessories (Supplied)
Model 6005 Test Socket
Model 6008 Test Socket
Model 6007 Program Card

Model 5001 Operational Manifold



Teledyne Philbrick Model 5001 Operational Manifold offers the engineer unprecedented flexibility in designing analog circuits. It is designed to provide the capabilities of simulating small analog systems and performing computations using plug-in Function Boards that accept many types of operational amplifiers as well as linear and non-linear function modules. This removes any restrictions the engineer would have in selecting amplifiers or using function modules in his breadboard design. The Model 5001's versatility proves invaluable for applications requiring varied types of computing elements.

In addition to its dynamic breadboard characteristics the Model 5001 is an outstanding educational tool for learning analog theory and circuit design from the basics through complex analog computation and control.

The Model 5001 incorporates a built-in regulated dual power supply which provides the Function Boards with ±15V dc at 100 mA, regulated typically to ±0.01% to line, and ±0.015% to load. The regulated voltages are brought out to Function Board jacks for use as input or reference voltages.

Each Function Board provides a socket for the active operator, and a logical patch field for connecting active and passive elements and interfacing associated circuitry. The boards can be removed or replaced quickly and easily by removing the screws that lock them in place.

Circuit wiring and interface is performed using banana plug patch cables, shorting bars, and plug-in passive and active elements. External signals and output indicators are connected in the same manner.

The patch field greatly reduces breadboarding time normally required for testing applications. When used for teaching purposes the patch field makes a lucid, easy-to-follow circuit.

The Model 5001 is available as a bench model or in a standard, 19-inch rack model. A complete line of accessories is available which includes a variety of Function Boards, hardware kits, and component kits. New Function Boards will be added as accessories when new products or applications arise.

SPECIFICATIONS

ELECTRICAL

INPUT VOLTAGE	115/230 ± 10%, 50–400 Hz
POWER SUPPLY	
Output Voltage	± 15, ± 0.15V dc
Output Current	± 100 mA min.
Regulation to line	± 0.03% max.
Regulation to load	± 0.03% max.
Ripple and Noise	1.0 mV rms
Short Circuit Protection	Complete protection against shorts for an indefinite period

MECHANICAL

DIMENSIONS	17"L x 12"W x 7.75"H
WEIGHT	6 lbs. (without Function Boards)
NO. CHANNELS	6 single boards or 3 double boards
HARDWARE	Banana Jacks

ACCESSORIES

MODEL 6048 FUNCTION BOARD

This Function Board is designed to accept standard 7 or 9 pin "Q" package operational amplifiers. The patch field for interconnecting operational elements includes jacks for external trim, ±15V dc regulated, signal ground and power ground.

MODEL 6042 FUNCTION BOARD

This Function Board is designed to accept integrated circuit operational amplifiers similar to the 709's in the TO-5 package. The patch field includes jacks for external trim, damping networks, ±15V dc regulated, signal grounds and power grounds.

MODEL 6049 FUNCTION BOARD

This version accepts our Model 4850 Three-Mode Integrator and will perform Sample and Hold, SPDT switching and integration. The patch field clearly illustrates the integral operating elements of the Model 4850 and includes two mounted trim pots to simplify circuit operation and layout. Model 6049 is a double size board and comes supplied with a Model 4850. Refer to page 24 for detailed specifications on Model 4850.

MODEL 6054 FUNCTION BOARD

This Function Board accepts the Teledyne Philbrick Models 4350 or 4351 Log Modules and provides an output proportional to the log or antilog of the input signal. The patch field clearly illustrates the integral operating elements and includes a mounted trim pot to simplify circuit layout and operation. Either a Model 4350 or 4351 is supplied with this double-size function board (specify). Refer to page 22 for detailed 4350/4351 specifications

MODEL MAK–2F CONNECTION HARDWARE KIT

4 shielded twin tip cables
12 single tip patch cords
32 twin tip plugs (for component mounting)
15 twin tip shorting plugs

MODEL CCK–MF COMPUTING COMPONENT KIT

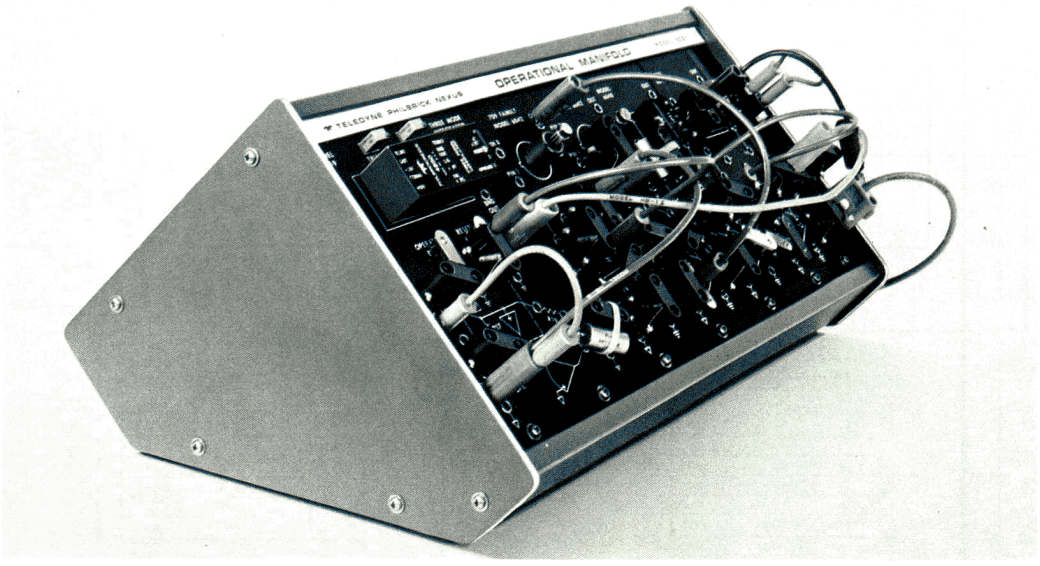
The CCK–MF Kit includes the following components mounted on twin tip banana plugs.
4 Diodes 1N914
2 Zener Diodes 9.5V, 5%

Resistors:
(2) ½ W, metal film, 100Ω, 1%
(2) ½ W, metal film, 1kΩ, 1%
(2) ½ W, metal film, 2kΩ, 1%
(2) ½ W, metal film, 4.99kΩ, 1%
(8) ½ W, metal film, 10kΩ, 1%
(8) ½ W, metal film, 20kΩ, 1%
(2) ½ W, metal film, 49.9kΩ, 1%
(4) ½ W, metal film, 100kΩ, 1%
(2) ½ W, metal film, 200kΩ, 1%
(2) ½ W, metal film, 499kΩ, 1%
(4) ½ W, metal film, 1MΩ, 1%
(2) 1 W, comp. 10MΩ, 2%

Capacitors
(4) mica 100V, 100pF, 20%
(4) mica 100V, 1000pF, 20%
(2) polystyrene, 100V, 0.01μF, 1%
(2) polystyrene, 100V, 0.1μF, 1%
(1) polystyrene, 100V, 1μF, 1%
(4) ceramic 50V, 0.1μF, +80%, -20%

ORDERING INFORMATION

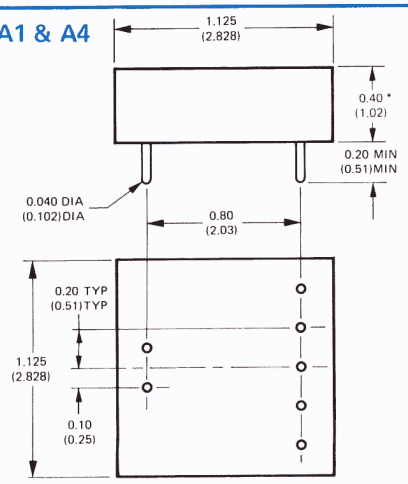
Model 5001 (specify bench or rack model)	$129.00
Model 6042 Function Board (less operator)	$ 20.00
Model 6048 Function Board (less operator)	$ 20.00
Model 6049 Function Board (Model 4850 Three Mode Integrator supplied)	$215.00
Model 6054 Function Board (Model 4350 or 4351 Log Module supplied – please specify)	$138.00
MAK–2F Connection Hardware Kit	$115.00
CCK–MF Computing Component Kit	$151.00



MECHANICAL SPECIFICATIONS

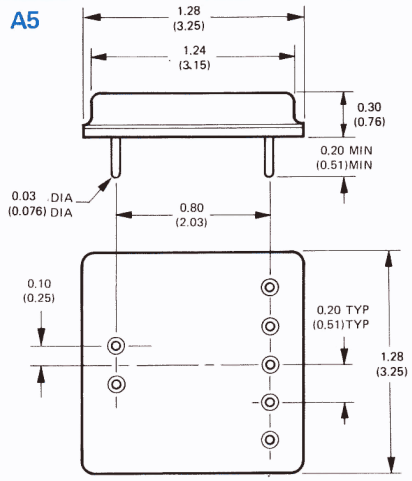
Dimensions in parentheses are expressed in centimeters

A1 & A4

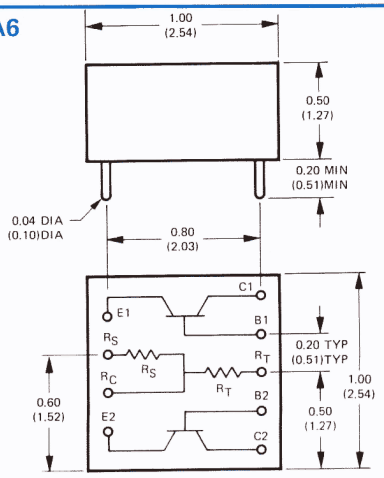


*Case style A1 Height is 0.59 (1.40)

A5



A6

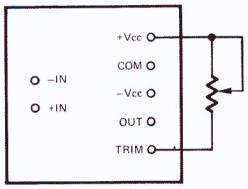


MODELS 4357 & 4358

MODEL	CASE	DIAGRAM	TRIM VALUE
SQ-10a	A1	A	50 kΩ RHST
Q-200	A1	B	1 MΩ POT (OPT)
1005	A1	A	50 kΩ RHST
1006	A1	B	1 kΩ POT
1008	A1	A	1 kΩ RHST
1009/01/02	A1	A	1 kΩ RHST
1011/01/02	A4	A	1 kΩ RHST
1017	A1	C	1 MΩ POT
1018/01-04	A1	A	**
1020/01-03	A1	A	**
1021	A1	A	2 kΩ RHST
1023/01	A1	A	**
1024	A1	A	10 kΩ RHST
1026*	A1	A	1 kΩ RHST
1027/01	A4	A	1 kΩ RHST
1412	A5	D	50 kΩ POT
4450	A1	D	50 kΩ POT

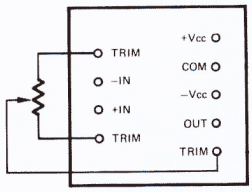
*COMMON PIN NOT USED **METAL FILM RESISTORS

DIAGRAM A



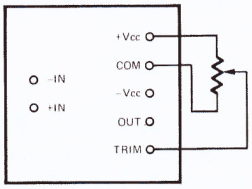
Bottom View

DIAGRAM B



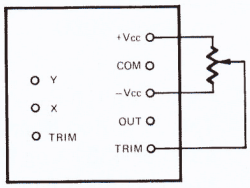
Bottom View

DIAGRAM C



Bottom View

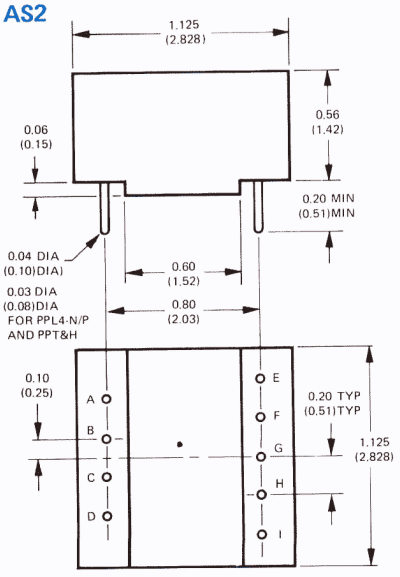
DIAGRAM D



Bottom View

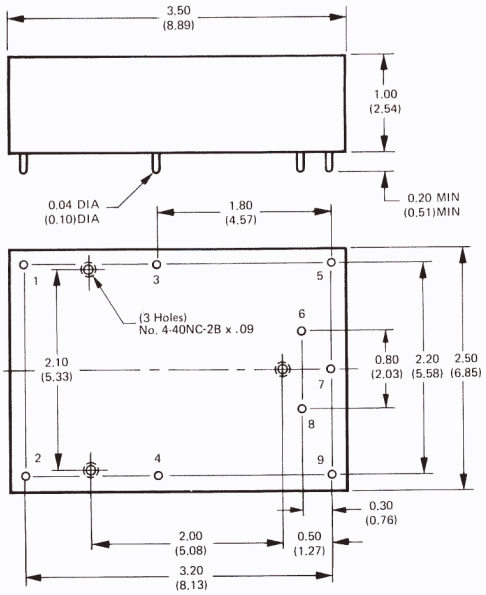
FOR MODEL 1412:
PIN Y IS INPUT
PIN X IS SIGNAL GROUND
TRIM PIN NOT USED
Common Pin Tied to Case

AS2



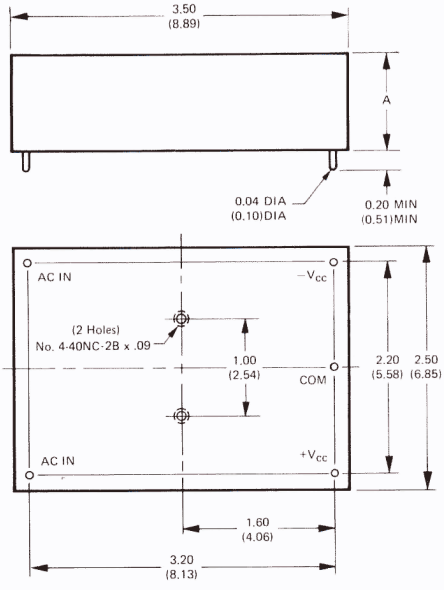
PIN	BQ-100	PPL4-N/P	PPT&H
A	–	3	SIG IN
B	NC	SUM PT	–IN
C	IN	SIG GRD	+IN
D	–	2	HQ GRD
E	+Vcc	+Vcc	+Vcc
F	COM	COM	COM
G	–Vcc	–Vcc	–Vcc
H	OUT	INPUT	OUT
I	NC	1	LOGIC

C1



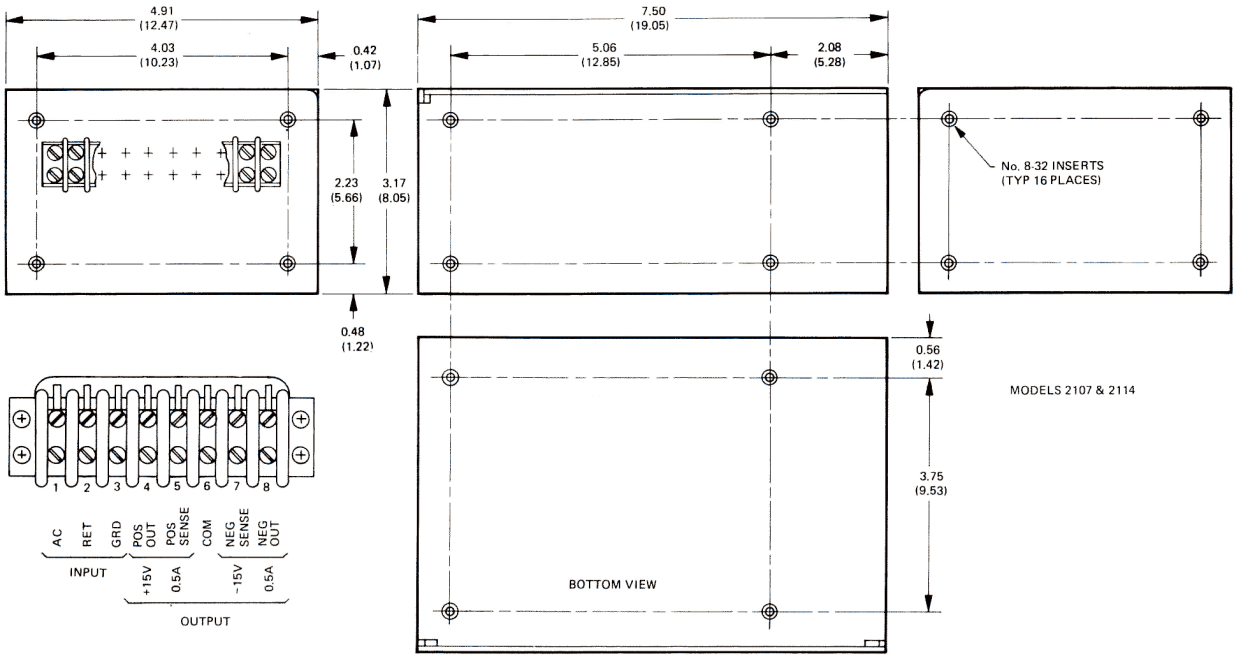
PIN	2203 2204	2206
1	AC	AC
2	AC	AC
3	AC	AC
4	AC	AC
5	–Vc	N.C.
6	TRIM	NO PIN
7	COM	COM
8	TRIM	NO PIN
9	+Vc	+Vc

C3, C4, & C5

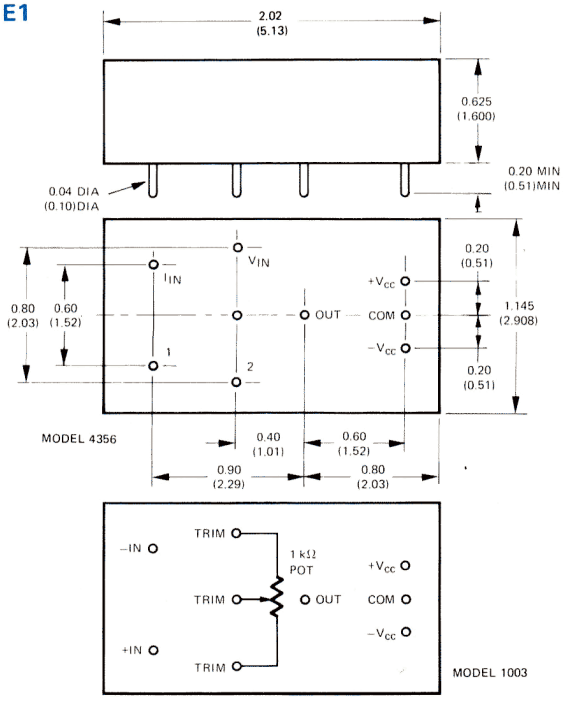


Model	Height A	Case
2208	1.00	C3
2209	1.00	C3
2210	0.88	C4
2211	0.88	C4
2212	1.00	C3
2213	1.25	C5

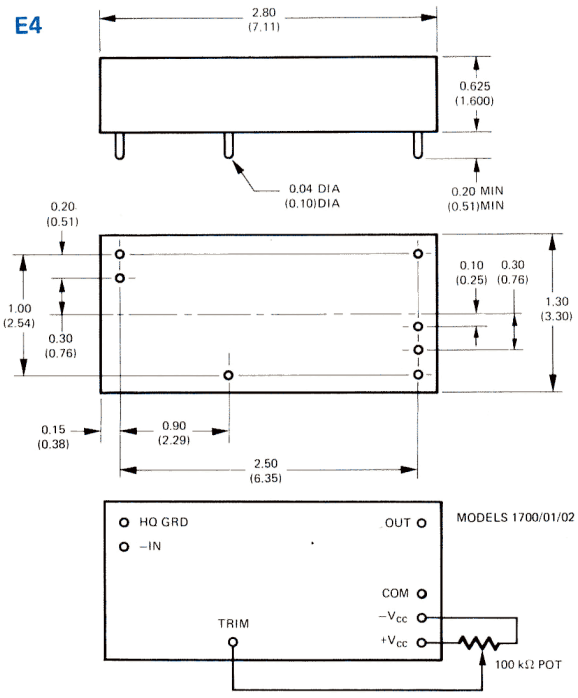
C2


4.91 (12.47)
4.03 (10.23)
0.42 (1.07)
7.50 (19.05)
5.06 (12.85)
2.08 (5.28)
2.23 (5.66)
3.17 (8.05)
0.48 (1.22)
No. 8-32 INSERTS (TYP 16 PLACES)
0.56 (1.42)
3.75 (9.53)
BOTTOM VIEW
MODELS 2107 & 2114
1 2 3 4 5 6 7 8
AC RET GRD POS OUT POS SENSE COM NEG SENSE NEG OUT
INPUT
+15V 0.5A -15V 0.5A
OUTPUT

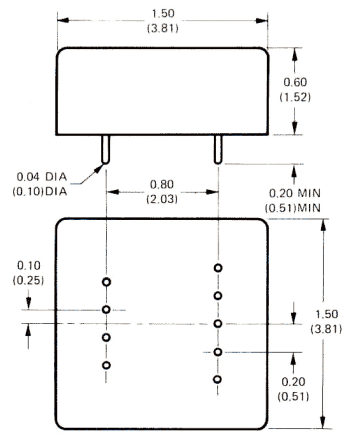
E1

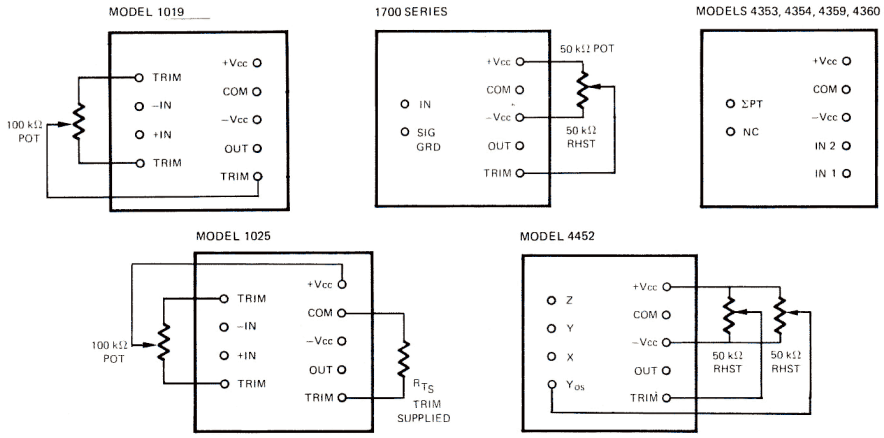

2.02 (5.13)
0.625 (1.600)
0.20 MIN (0.51)MIN
0.04 DIA (0.10)DIA
VIN
IIN
OUT
+Vcc
COM
-Vcc
0.80 (2.03)
0.60 (1.52)
0.20 (0.51)
1.145 (2.908)
0.20 (0.51)
MODEL 4356
0.40 (1.01)
0.60 (1.52)
0.90 (2.29)
0.80 (2.03)
TRIM
1 kΩ POT
-IN
+IN
OUT
MODEL 1003

E4

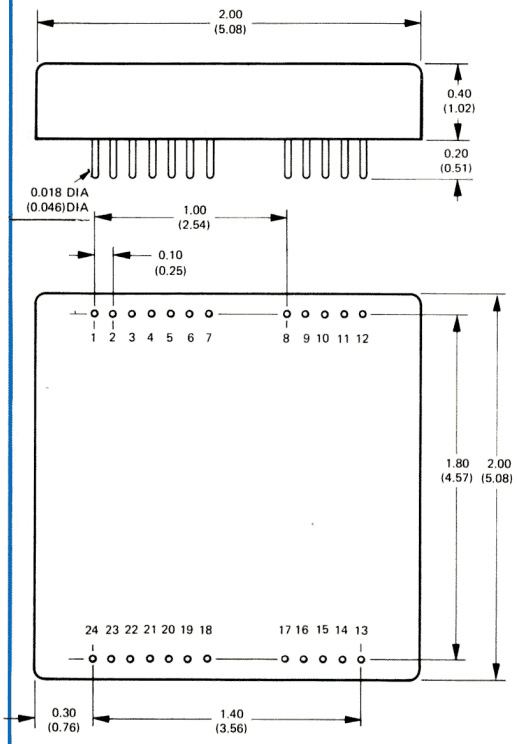

2.80 (7.11)
0.625 (1.600)
0.04 DIA (0.10)DIA
0.20 MIN (0.51)MIN
0.20 (0.51)
0.10 (0.25)
0.30 (0.76)
1.30 (3.30)
1.00 (2.54)
0.30 (0.76)
0.15 (0.38)
0.90 (2.29)
2.50 (6.35)
HO GRD
-IN
OUT
COM
-Vcc
+Vcc
TRIM
MODELS 1700/01/02
100 kΩ POT

E5


1.50 (3.81)
0.60 (1.52)
0.04 DIA (0.10)DIA
0.80 (2.03)
0.20 MIN (0.51)MIN
0.10 (0.25)
1.50 (3.81)
0.20 (0.51)


MODEL 1019
TRIM
-IN
+IN
TRIM
+Vcc
COM
-Vcc
OUT
TRIM
100 kΩ POT
1700 SERIES
IN
SIG GRD
50 kΩ POT
50 kΩ RHST
MODELS 4353, 4354, 4359, 4360
ΣPT
NC
IN 2
IN 1
MODEL 1025
RTS TRIM SUPPLIED
MODEL 4452
Z
Y
X
Yos
50 kΩ RHST
50 kΩ RHST

E6



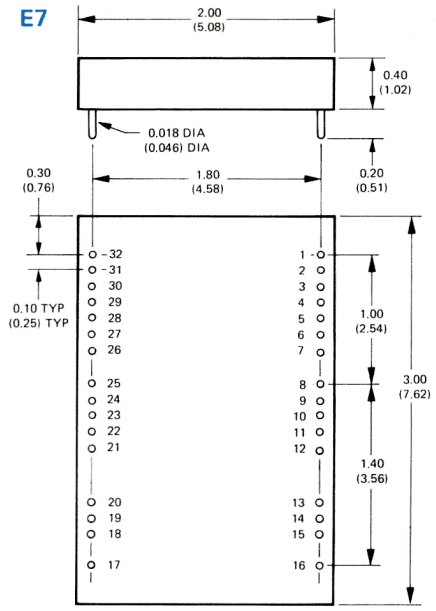
DIGITAL TO ANALOG CONVERTERS

PIN	4004 4005	4008 4009	4010 4011	4022 4023	4020 4021
1	BIT 1				
2	BIT 2				
3	BIT 3				
4	BIT 4				
5	BIT 5				
6	BIT 6				
7	BIT 7				
8	BIT 8				
9	BIT 9				NOT USED
10	BIT 10				
11	BIT 11		NOT USED		
12	BIT 12		NOT USED		
13	I_{OUT}				
14	V_{OUT}				
15	NOT USED				
16	MODE	NOT USED	MODE		
17	REF OUT				
18	+15 VDC				
19	GROUND				
20	−15 VDC				
21	NOT USED				
22	+REF IN				
23	−REF IN				
24	EXT REF				

NOTES ON D–A CONVERTERS

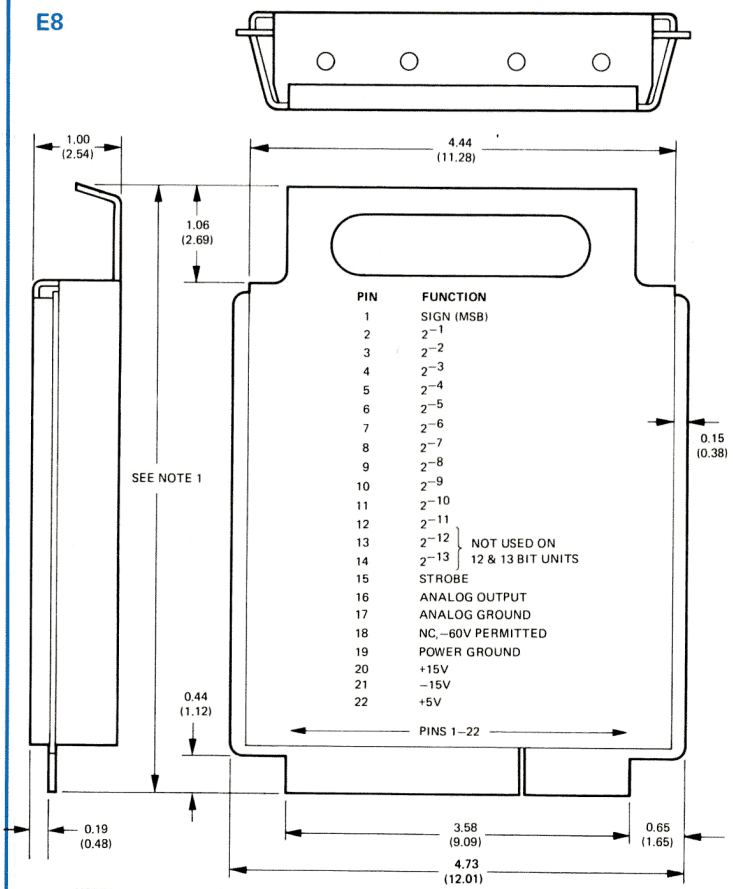
1. UNIPOLAR MODE–CONNECT PIN 16 TO GROUND PIN 19
2. BIPOLAR MODE–CONNECT PIN 13 TO 16
3. PINS 13 AND 16 USED IN CURRENT CONVERTER ONLY.
4. PIN 14 USED IN VOLTAGE CONVERTER ONLY.
5. TO INSURE STABLE OPERATION, POWER SUPPLY BYPASSING WITH 0.01 μF DISC CAPACITOR IS RECOMMENDED.
6. BECAUSE OF THE HIGH SPEED BUFFER INPUTS IN THE DAC'S IT IS RECOMMENDED THAT ANY DIRECT GROUNDING OF DIGITAL INPUTS BE DONE THROUGH 100Ω RESISTORS TO PREVENT OSCILLATIONS. HOWEVER, THIS IS NOT NECESSARY IF THE INPUTS ARE DRIVEN DIRECTLY FROM A DTL OR TTL SOURCE.

E7



PIN	4109/01 4111/01	4110			
1	BIT 1	BIT 1	16	−15V	NO PIN
2	BIT 2	BIT 2	17	NO PIN	NO PIN
3	BIT 3	BIT 3	18	NO PIN	NO PIN
4	BIT 4	BIT 4	19	INPUT	NO PIN
5	BIT 5	BIT 5	20	ANALOG GND	NO PIN
6	BIT 6	BIT 6	21	DIGITAL GND	INHIBIT
7	BIT 7	BIT 7	22	+5V	CLOCK B
8	BIT 8	BIT 8	23	OVER RANGE	TRACK HIGH
9	BIT 9	LOW LIMIT	24	COMP	TRACK LOW
10	BIT 10	HIGH LIMIT	25	NO PIN	DIGITAL GND
11	BIT 11	RESET	26	OFFSET	CLOCK A
12	BIT 12	+5V	27	RECYCLE	+15V
13	NO PIN	NO PIN	28	RESET	COM
14	+15V	NO PIN	29	$\overline{\text{BIT 1}}$	−15V
15	NO PIN	NO PIN	30	NO PIN	NO PIN
			31	NO PIN	OFFSET
			32	NO PIN	V_{IN}

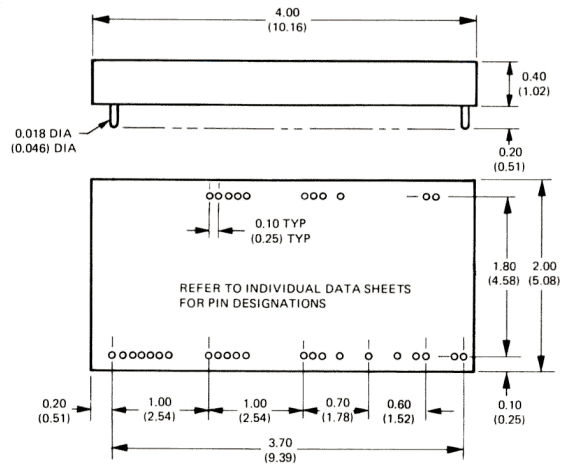
E8



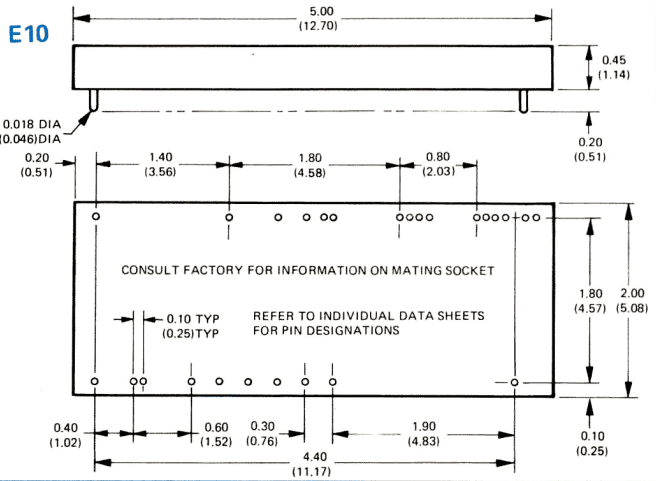
PIN	FUNCTION
1	SIGN (MSB)
2	2^{-1}
3	2^{-2}
4	2^{-3}
5	2^{-4}
6	2^{-5}
7	2^{-6}
8	2^{-7}
9	2^{-8}
10	2^{-9}
11	2^{-10}
12	2^{-11}
13	2^{-12} } NOT USED ON
14	2^{-13} } 12 & 13 BIT UNITS
15	STROBE
16	ANALOG OUTPUT
17	ANALOG GROUND
18	NC, −60V PERMITTED
19	POWER GROUND
20	+15V
21	−15V
22	+5V

NOTES:
1. HEIGHT FOR MODEL 4002 IS **6.31 (16.03)**. HEIGHT FOR MODELS 4015, 4017, 4019 is **8.13 (20.64)**
2. KEY SLOT (0.062) IS LOCATED BETWEEN PINS 16 AND 17.
3. DISTANCE BETWEEN FINGER CENTERS IS 0.156.
4. MATING CONNECTOR IS 22 PIN CINCH 250-22-30-170 OR EQUIVALENT (SUPPLIED)

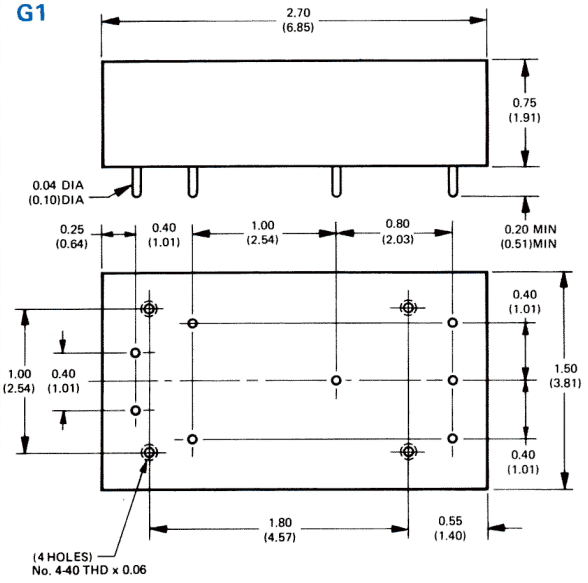
E9

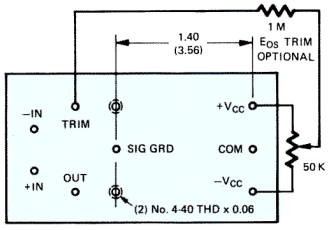


E10

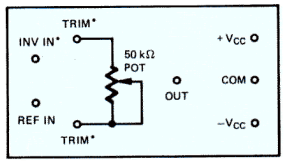


G1

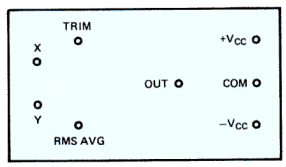




4361

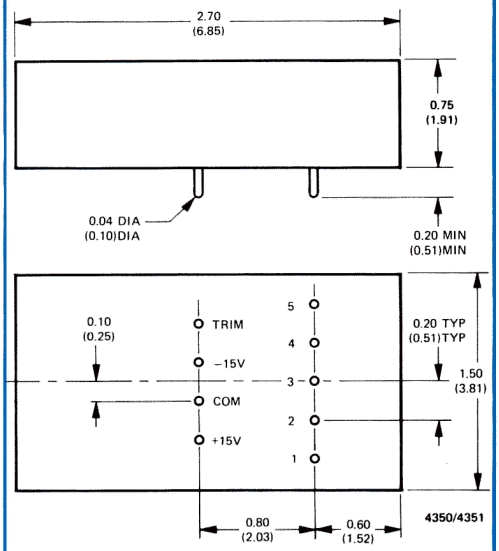


*PINS NOT USED ON MODEL 2001 1016 & 2001



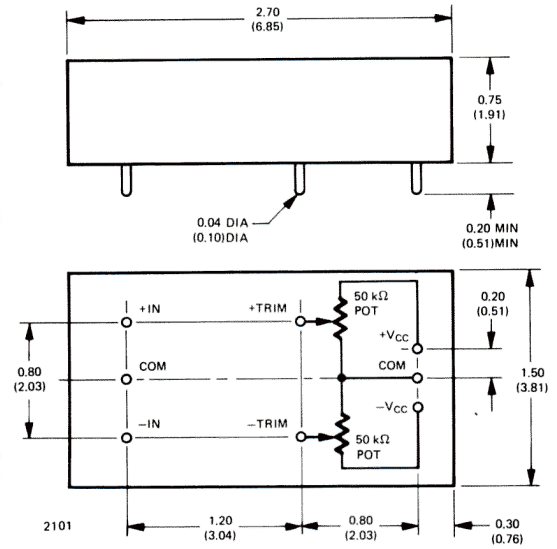
4352

G2

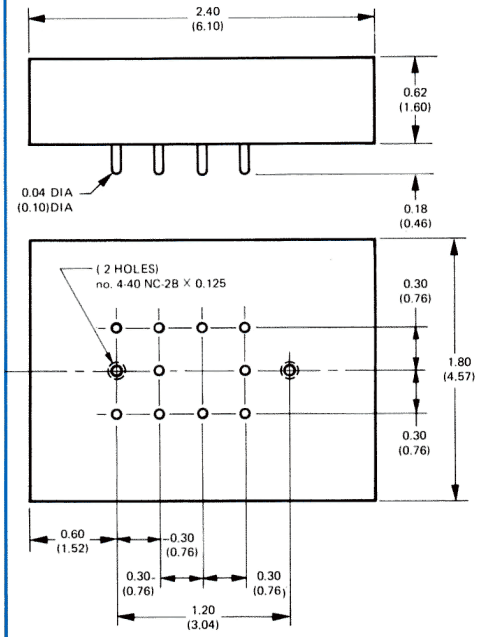


4350/4351

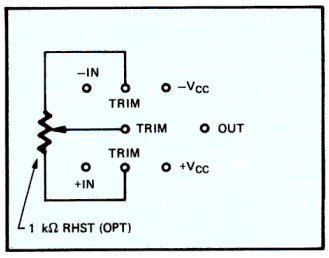
G3



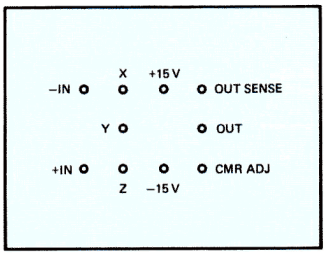
2101



G4

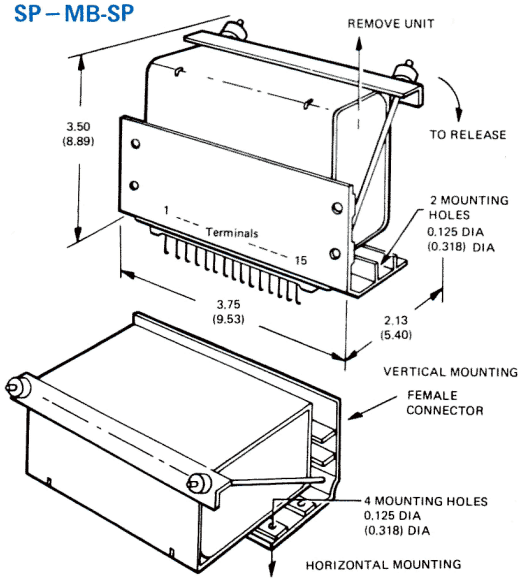


1022



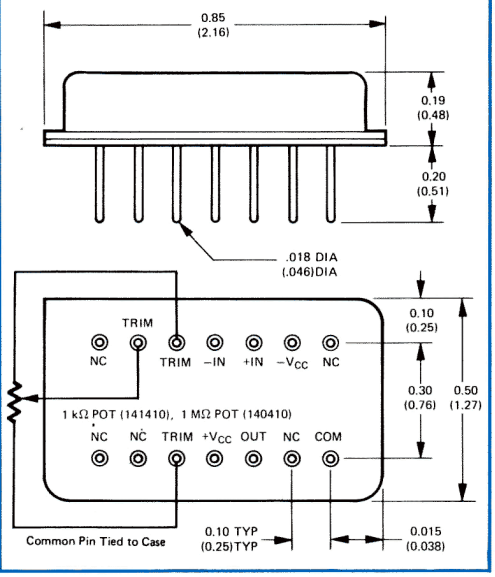
4251 4252

SP – MB-SP

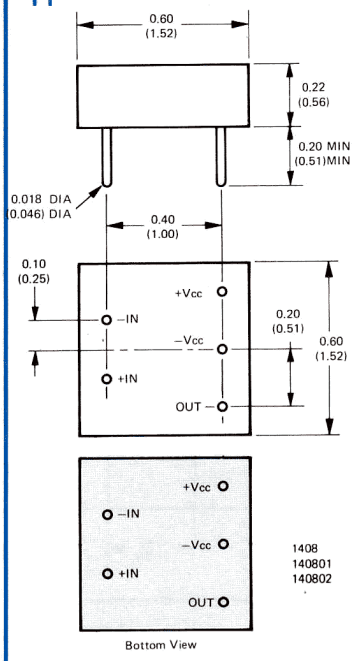


PIN	OSPB-100/10	SPFX-N/P	SP2A SP2AU	170021/22/23
1	OUT	NC	OUT	OUT
2	–120 V	–15 V	–15 V	–15
3	+120 V	+15 V	+15 V	+15
4	KEY	NC	COM	NC
5	INV. IN	NC	GUARD	HQ GND
6	NC	KEY	+IN	INT GND
7	INPUT	ΣPT 1	–IN	ΣPT
8	COM	COM	COM	COM
9	NC	IN	KEY	KEY
10	KEY	ΣPT 2	NC	NC
11	–BOOST R	NC	COM	NC
12	–BOOST R	NC	NC	NC
13	+BOOST R	NC	NC	NC
14	GROUND	NC	CASE	CASE
15	GROUND	CASE	CASE	CASE

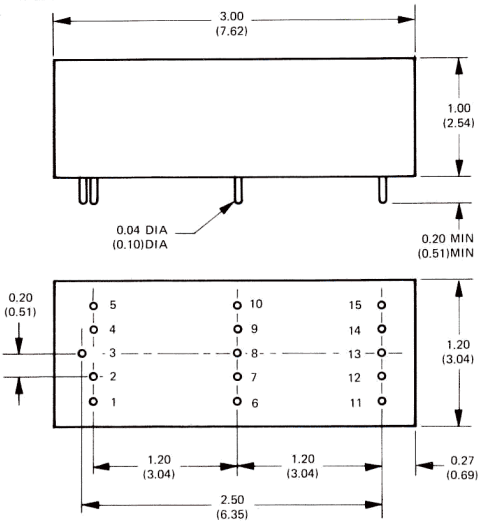
S4



T1

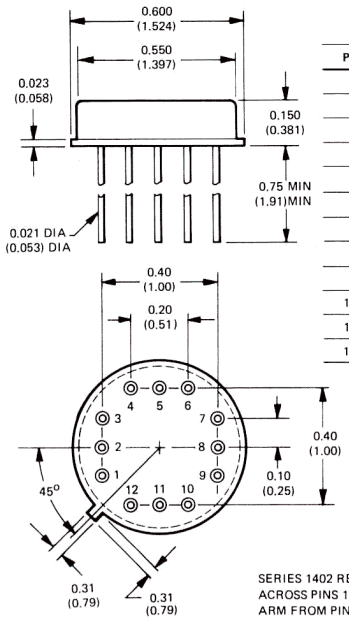


T10



1. OPERATE INPUT
2. OPERATE REF. INPUT
3. RESET INPUT
4. INITIAL CONDITION SUMMING POINT
5. RESET REFERENCE INPUT
6. SWITCHED SUMMING POINT
7. SUMMING POINT
8. SIGNAL GROUND
9. BOUND DETECTOR
10. TRIM A-2 (CURRENT AMP)
11. +15V
12. COMMON
13. –15 V
14. OUTPUT
15. TRIM A-1 (MAIN AMP)

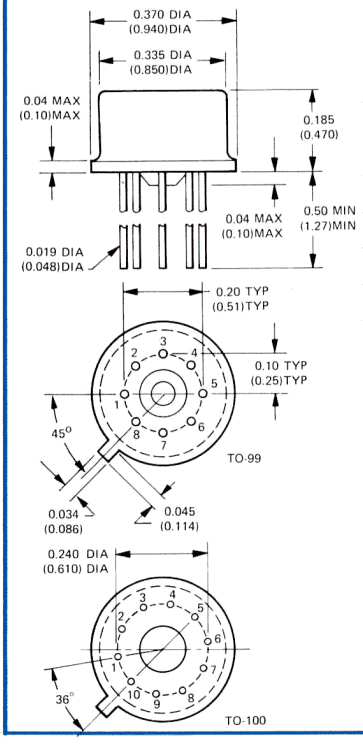
TO-8



PIN	1402/01/02	140810
1	TRIM	+IN
2	TRIM	–IN
3	TRIM	NC
4	+IN	+15 V
5	$-V_{CC}$	COM
6	NC	–15
7	NC	GND
8	OUT	OUT
9	NC	NC
10	CASE	NC
11	$+V_{CC}$	NC
12	–IN	NC

SERIES 1402 REQUIRES A 1 kΩ POT ACROSS PINS 1 AND 3 WITH THE ARM FROM PIN 2.

TO-99 & TO-100

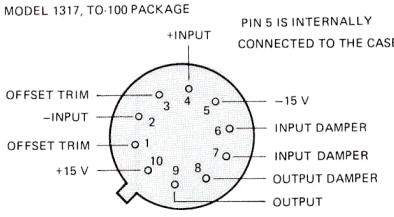


PIN	1301	1319/1339 1321/1322	1323	1413 1420
1	FIRST DAMPER	OFFSET ADJUST	OFFSET ADJUST	OFFSET NULL
2	–IN	–IN	–IN	–IN
3	+IN	+IN	+IN	+IN
4	–15 V	–15 V	–15 V	–15 V
5	OUTPUT DAMPER	OFFSET ADJUST	NC	OFFSET NULL
6	OUTPUT	OUTPUT	OUTPUT	OUTPUT
7	+15 V	+15 V	+15 V	+15 V
8	FIRST DAMPER	BANDWIDTH* CONTROL	OFFSET ADJUST	NC

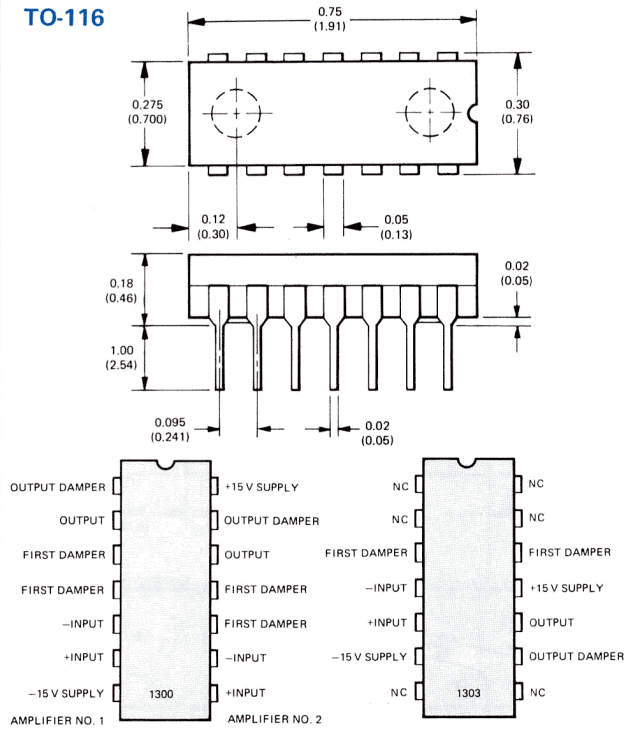
* PIN 8 IS NC ON MODELS 1319

MODEL 1317, TO-100 PACKAGE

PIN 5 IS INTERNALLY CONNECTED TO THE CASE

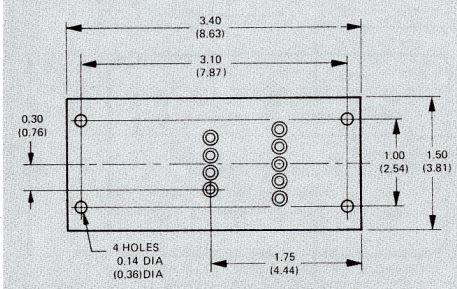


TO-116



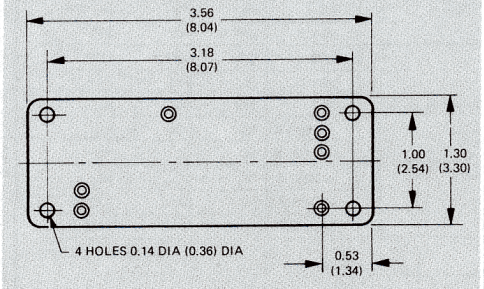
Sockets

6003



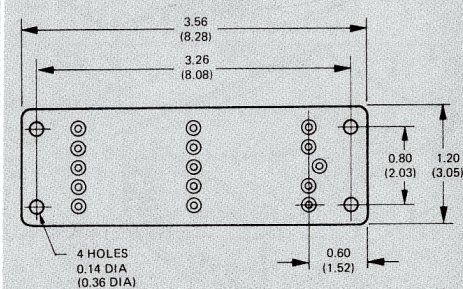
BOARD THICKNESS: 0.09 (0.23) EPOXY
OVERALL HEIGHT: 0.68 (1.73)

6023



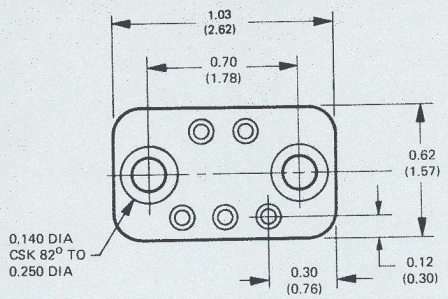
BOARD THICKNESS: 0.09 (0.23) ALUMINUM
OVERALL HEIGHT: 0.50 (1.27)

6024



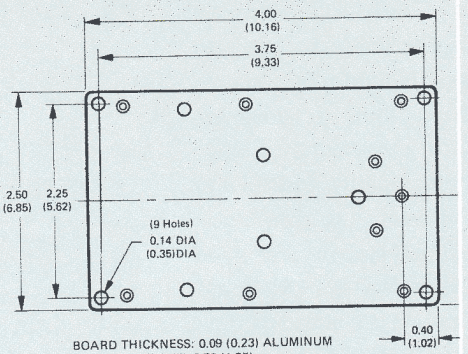
BOARD THICKNESS: 0.09 (0.23) EPOXY
OVERALL HEIGHT: 0.68 (1.73)

6035



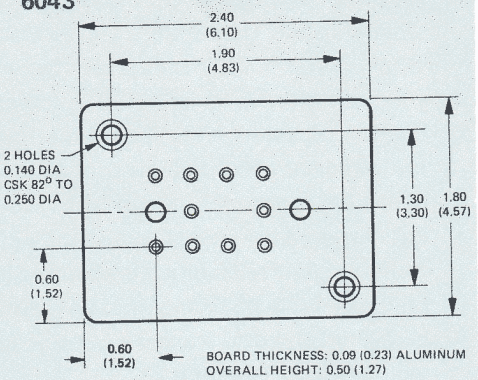
BOARD THICKNESS: 0.09 (0.23) EPOXY
OVERALL HEIGHT: 0.68 (1.73)

6036



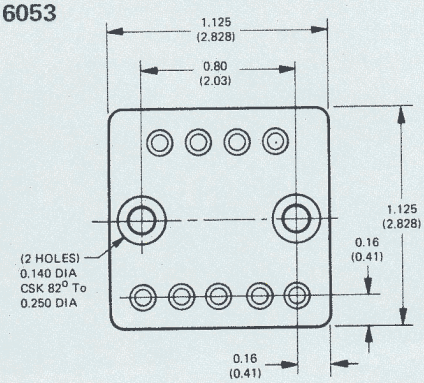
BOARD THICKNESS: 0.09 (0.23) ALUMINUM
OVERALL HEIGHT: 0.50 (1.27)

6043



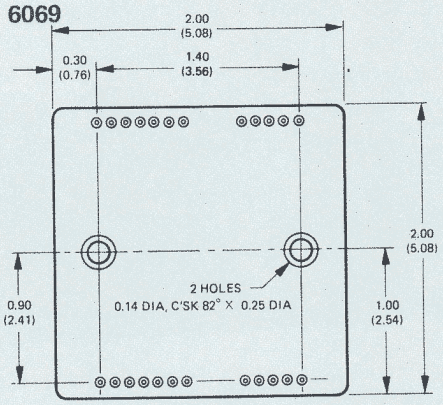
BOARD THICKNESS: 0.09 (0.23) ALUMINUM
OVERALL HEIGHT: 0.50 (1.27)

6053



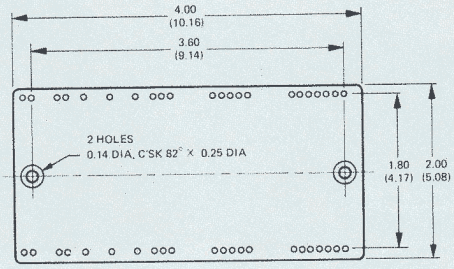
BOARD THICKNESS: 0.09 (0.23) ALUMINUM
OVERALL HEIGHT: 0.50 (1.27)

6069



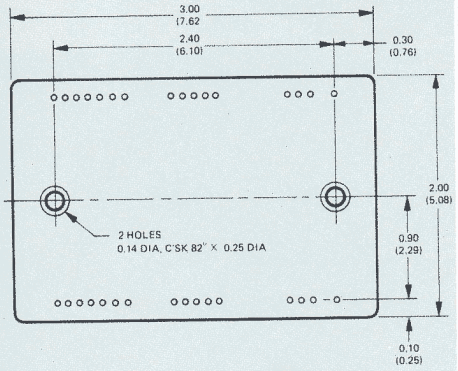
BOARD THICKNESS: 0.09 (0.23) ALUMINUM
OVERALL HEIGHT: 0.50 (1.27)

6121



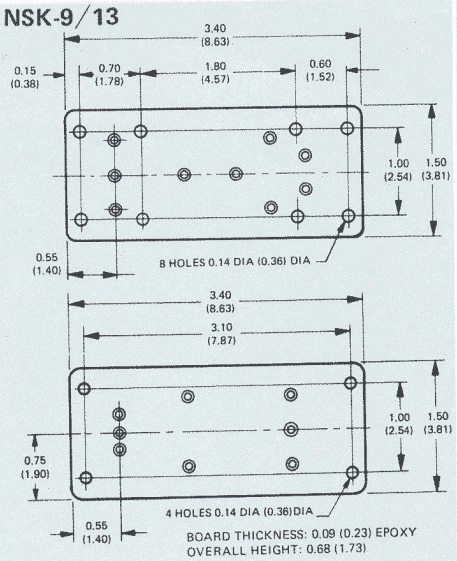
BOARD THICKNESS: 0.09 (0.23) ALUMINUM
OVERALL HEIGHT: 0.50 (1.27)

6122



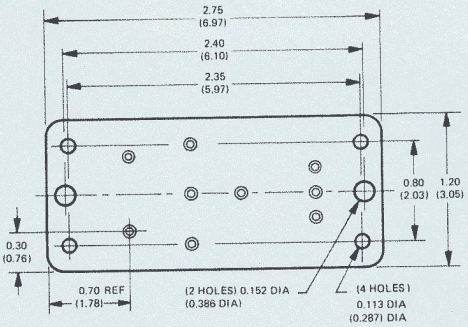
BOARD THICKNESS: 0.09 (0.23) ALUMINUM
OVERALL HEIGHT: 0.50 (1.27)

NSK-9/13



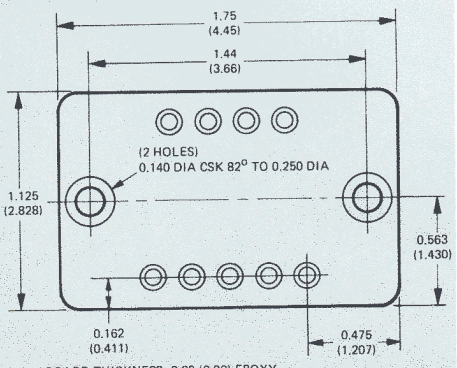
BOARD THICKNESS: 0.09 (0.23) EPOXY
OVERALL HEIGHT: 0.68 (1.73)

NSK-14



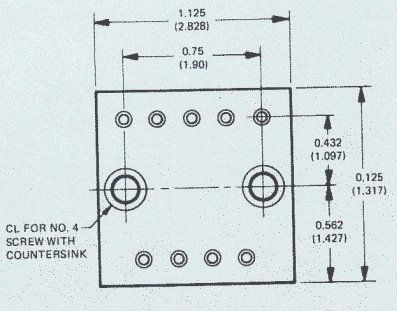
BOARD THICKNESS: 0.09 (0.23) EPOXY
OVERALL HEIGHT: 0.68 (1.73)

NSK-20



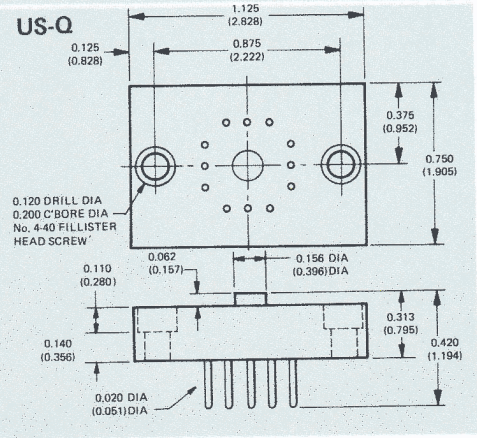
BOARD THICKNESS: 0.09 (0.23) EPOXY
OVERALL HEIGHT: 0.68 (1.73)

US-PP

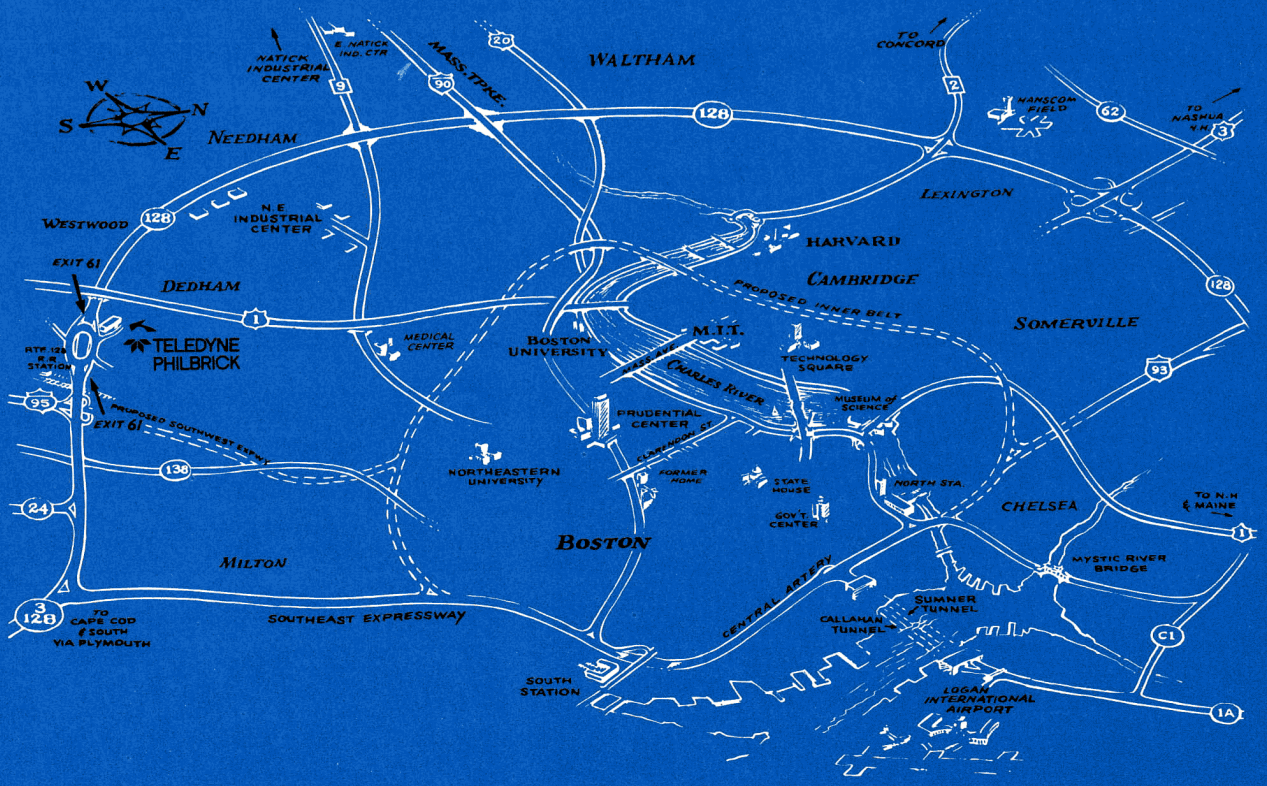


BOARD THICKNESS: 0.125 (0.318) EPOXY
OVERALL HEIGHT: 0.43 (1.08)

US-Q



All design and manufacturing facilities are located in this modern facility just off Route 128... greater Boston's famous "Electronics Row". Operations include manufacturing facilities for discrete component products as well as a complete thick-film hybrid production capability. The facility has been carefully designed for high efficiency/high volume production. All manufacturing operations are constantly monitored by both the quality control and engineering departments to insure strict adherence to design performance and reliability... traditional hallmarks of the Teledyne Philbrick product line. Visitors are always welcome and you are cordially invited to inspect our plant (a phone call ahead of time will insure VIP treatment).



CUSTOMER SERVICE

Ordering Information

TO HELP YOU PLACE YOUR ORDER

Teledyne Philbrick offers a widely diversified line of functional circuit modules and test instruments – each with a different combination of performance capabilities, input and output characteristics, and price. Thus, there is generally an optimum choice for you – One most ideally compatible with your particular performance and budgetary requirements. You will often find that more than one model seems to be in that category. Then, a brief technical discussion with your Teledyne Philbrick Engineering Representative will make it easier for you to select the best of multiple choices.

In most cases, the fastest and most efficient source of information on products, applications, and services is your local Engineering Representative. For highly specialized technical information, your Representative may suggest that you confer directly with Applications Engineers at our factory. Your letter or call is always welcome and will receive our total and immediate attention.

For applications where you require operational testing for proper evaluation – or where operational experience is required to assist you in determining suitable performance requirements, your Engineering Representative is able to arrange trial use of appropriate equipment – as well as installation and operating assistance.

To keep pace with the increasing demand for off-the-shelf delivery of functional circuit modules, Philbrick has just added a distributorship to its service network. The distributor, Intermark Electronics, will service customers in the West Coast and Rocky Mountain regions. In addition, Philbrick has also installed a telephone Wats line to offer toll free applications and product assistance 24 hours a day. For complete details see the back cover.

No matter where you are located in the world, you may place your order directly with us or through your nearest Philbrick Engineering Representative. (Note: If we do not yet have a representative in your country, please contact us directly.) REPRESENTATIVES STOCK AMPLE QUANTITIES OF STANDARD PRODUCTS, THUS CAN OFFER SAME-DAY DELIVERY. Prices listed in this catalog are F.O.B. Factory, Dedham, Massachusetts, U.S.A; quotations on custom items, quantity orders, and other price information will be furnished by your local representative on request. Quotations are normally valid for thirty days.

As a special convenience feature, postage-paid cards for in-depth product and application information and service requests are included in this catalog.

TO HELP US PROCESS YOUR ORDER – QUICKLY

Please specify model numbers and model names. For example: "Model 1006, Differential Operational Amplifier" or "Model 5001, Operational Manifold." Be sure to include the prefix or suffix on certain model numbers to identify special versions of the product.

If your purchase order is a confirmation of an advance verbal order, it should be sent to the office where the advance order was placed. All confirmations should be marked "CONFIRMATION ONLY – DO NOT DUPLICATE."

Acknowledgements will be sent out promptly by us for United States and Canadian orders on Teledyne Philbrick's standard acknowledgement forms.

MODIFICATIONS TO EQUIPMENT – Special identification markings and other minor modifications can generally be made available at a slight increase in price and delivery time. Your inquiries and specifications should be directed to your Philbrick Engineering Representative.

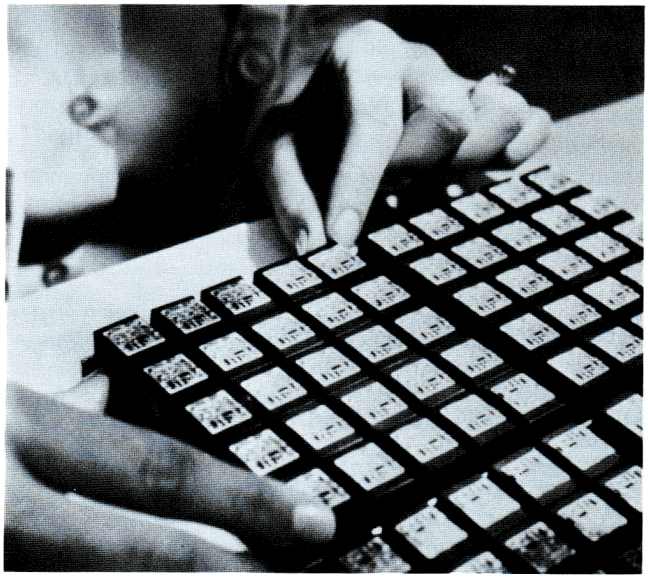
REGARDING SHIPMENT OF YOUR ORDER

Shipments to destinations within the United States are normally made directly from the factory in Dedham, and are billed F.O.B. Dedham, Massachusetts. Local representatives or distributors (on the West Coast) should be contacted first for small quantity purchases as the units may be available from their stock. Shipments to other parts of the world are from the local representative's stock or directly from the factory.

TERMS AND CONDITIONS OF SALE

The minimum order accepted by Philbrick is $25.00. On all orders, unless alternative arrangements have been made in advance, payment is due NET 30 DAYS following date of shipment. Foreign payments and terms are arranged on an individual basis by Philbrick's International Sales Department.

All prices listed in this catalog are subject to change without advance notice. Unit prices, as listed, do not include state or local taxes. Where applicable, these taxes will be reflected on your invoice.



FULLY COMPUTERIZED ORDER PROCESSING

Rapid delivery of all product orders is an especially important part of our total service philosophy. Accordingly, our fully computerized order processing system, in conjunction with our large-scale, automated production lines, a prototype department geared to the production of special, small quantity, and custom devices, and a carefully maintained inventory control – systematically expedite shipment of your equipment, which will, whenever possible, be en route to its destination less than 24 hours after we have received your order.

WARRANTY

Limitation of Liability. Our goods are warranted by us to be free from defects of material or manufacture and to conform to the applicable published ratings and characteristics in effect at the time of shipment. Our liability under such warranty is limited to replacing or repairing, at our option, any goods found to be defective in such respects which are returned to us transportation prepaid within one year from the date of shipment. In no event shall we be liable for collateral or consequential damages. This warranty shall not apply to any goods which have been subjected to misuse, improper installation, repair, alteration, neglect, accident, inundation, fire or operation outside their published maximum ratings. We will have the right of final determination of the cause and existence of any defect under this warranty.

REPAIRS OR REPLACEMENT

In accordance with the conditions of the Warranty Statement, we ask that all apparently out-of-order equipment be returned to us, whether repairable or not, so that we can apply what we learn from any units having defects toward product improvements and new product designs.

If for any reason you wish to return equipment to us, please contact the Teledyne Philbrick sales office for a "Return Materials Authorization Form." *before* returning the equipment. Written authorization must first be obtained before returning any merchandise. Proceed according to the instructions on the RMA form. In case of emergency, contact the Teledyne Philbrick Sales Department directly for instructions. To expedite handling of your equipment, please enclose a copy of a letter stating model number, model name, serial number, date code, the reason for return, any applicable purchase order number, and your exact return address. The original of that letter should be addressed to Sales Department, Teledyne Philbrick, Allied Drive at Route 128, Dedham, Mass. 02026.

If any Philbrick unit requiring repair or replacement is a critical component or is part of a System requiring minimum down-time, please notify your Philbrick Engineering Representative immediately. He is often able to arrange for the loan of a temporary replacement unit.

Technical Literature

APPLICATIONS MANUAL FOR COMPUTING AMPLIFIERS

A comprehensive treatment of the operational amplifier – its application in numerous computing, controlling, and measurement operations. This 116 page manual is a good starter for the uninitiated and a handy reference thereafter. Price: $5.00. For teachers and accredited students, $3.50.

APPLICATIONS BULLETINS

Concise, informal sheets released periodically to illustrate salient, useful, and often new applications of feedback techniques.

DATA SHEETS

Each product manufactured by Philbrick is described in depth on an individual technical bulletin which includes electrical performance, physical and mechanical specifications, as well as descriptive data and circuit diagrams for employment of the device in typical applications.

With each shipment of equipment, a complete set of technical data is enclosed.

SHORT FORM SUPPLEMENTARY CATALOGS

Useful, comparative summaries of product families can be found in these short form catalogs. They will be made available, between catalog release dates, for all new instrumentation developed by Philbrick.

THE NEW LIGHTNING EMPIRICIST

First published in 1952, and named by George Philbrick "The Lightning Empiricist," this publication has been revived to help our friends, readers, and customers keep abreast of a rapidly changing state-of-the-electronic art.

Customer contributions are always welcome and earnestly solicited; current and back-issues are available on request.

You may request, at no additional cost, extra copies of any of the above materials. To receive mailed notices of all new literature as it is published, a copy of each new Lightning Empiricist, and each new Applications Bulletin, please use one of the postage-paid cards included in this catalog to request inclusion in our mailing list. Also, with the technical publications sent for each shipment, a return postcard is enclosed. With its return, your name will automatically be placed on a special user mailing list.

Field Engineering

Philbrick has carefully selected and trained hundreds of professional Field Engineering Representatives throughout the world to form a network of rapid, informed, on-the-spot product selection and applications assistance. By continually participating in our field education programs and special staff seminars, and maintaining regular contact with our factory engineering and product development departments, they are equipped to provide you with the most up-to-date, accurate information available. They welcome every opportunity to serve your needs – whether you are researching competitive equipment, up-dating the operations of equipment in use, or seeking service or suggestions.

Applications Engineering

Always on hand at our headquarters in Dedham, Massachusetts for contact by telephone letter or personal visit, is a staff of engineers highly skilled in the techniques and applications of circuit modules. These Engineers will gladly assist you, not only in discussing the suitability of our products and in the selection of the best unit to meet your needs, but also, where possible, in the selection and design of auxiliary circuit components and other custom equipment. Your inquiry is invited. . . call or write Applications Engineering, Teledyne Philbrick Dedham, Massachusetts 02026.

Educational Seminars

Each year, our Field Education program improves in quantity and in quality. We now offer a series of practical seminars in Operational Amplifiers and Instrumentation and many other phases of electronic instrumentation applications. . . designed to present these subjects either at the beginners level or for the specialist. These clinics are conveniently located in major metropolitan areas throughout the United States. Our International Department can now schedule similar seminars, clinics, and exhibition/demonstrations practically anywhere in the world upon request. These services are available without charge. Consult your local Philbrick Engineering Representative to make specific arrangements regarding date, location, and seminar content.

Military and NASA Applications

Philbrick maintains complete facilities for the manufacture of MIL-type operational amplifiers and Quality Assurance system in accordance with MIL-9858A and NPC 200-3.

Many of our hybrid amplifier types were specifically developed for aerospace applications and extensive reliability histories are available on request. These are tested at five temperatures (–55, –25, +25, +85, +125°C) and certified test data can be supplied. The monolithic models can be tested and certified in the same manner upon special order. They are hermetically sealed and meet MIL-S-19500 and MIL-STD-883.

Amplifiers with electrical specifications equal to or exceeding those of the models shown in this catalog can be built to the following standards:

COMPONENT CONFORMANCE

The component parts used conform to the requirements of the following MIL specifications as they apply (latest revision):

Fixed, Composition Resistors	MIL-R-11
Fixed, Film (High Stability) Resistors	MIL-R-10509
Fixed, Ceramic – Dielectric Capacitors	MIL-C-11015
Fixed, Tantalum Solid Electrolytic Capacitors	MIL-C-39003
Semiconductors	MIL-S-19500

PREMIUM AMPLIFIER CAPABILITY

Can be fabricated with MIL/QPL parts to meet MIL-E-16400 or equivalent

Can be constructed to operate at –55°C to +100°C or higher

Can be stored at –65°C to +125°C

Printed circuit boards in NASA amplifiers per MSFC-STD-154

Encapsulated under vacuum in high thermal conductivity epoxy per MSFC-PROC-412

Hand soldering per NPC 200-4

Solderers and encapsulators certified by NASA

Input overdrive and output short circuit protected

100% final testing over entire temperature range

Comprehensive documentation related to reliability and performance

Rigid lot control: all amplifiers serialized for traceability

Minimum MTF of 250,000 hours at 25°C per MIL-HDBK-217A

Quality controlled under MIL-Q-9858 and NPC 200-3 formats

Modules meet MIL-STD-202 or MIL-E-5272, as applicable, on vibration, shock, moisture resistance, altitude acceleration thermal shock and salt spray.

ENVIRONMENTAL TEST SUMMARY

Vibration
MIL-E-5272 Proc. XVI – 6 hours (2 hours each plane) 35-2000 Hz @ 20 G

Shock
MIL-E-5272 Proc. V, Para. 4.15.5.1 – 18 shocks, 3 each direction, each plane 15 G's 11 milliseconds

Moisture Resistance
MIL-STD-202 Method 106A – Ten days 25°C to 65°C 90-98% RH; steps 7a and 7b performed 5 of first 9 cycles

Altitude
MIL-STD-202 Method 105, Condition D – 0.315 in Hg (100,000 feet)

Acceleration
MIL-STD-202 Method 212, Condition A – 80 G's for 5 minutes each of 3 planes (non-operating)

Thermal Shock
MIL-STD-202 Method 107, Condition B – 5 cycles –65°C and +125°C (30 minutes each) transfer within 5 minutes

Salt Spray
MIL-STD-202 Method 101, Condition A – 96 hours at +35°C with approximately 85% humidity

HIGH PRECISION amplifiers in the metal SP cases can be built to similar standards; however, their operating and storage temperature ranges are more limited. Shock and vibration requirements can be met by filling the cases with a silicone rubber compound which leaves them factory-repairable. Philbrick has a wide range of MIL-type models in regular production, samples of which can be supplied on short notice. In every case premium grade equivalents can be used for prototyping while waiting for the militarized version.

PRODUCT INDEX

Testers

Accessories

Other Standard Products

*For data on these field-proven models, consult factory.

NATIONAL SALES REPRESENTATIVES & DISTRIBUTORS

EASTERN REGION

W. A. Brown Instruments, Inc.

961 N.W. 53rd St.
Ft. Lauderdale, Florida 33309
(305) 564-8000 (305) 566-5697
Telex 51-4475

18 Chelsea Drive
Fort Walton Beach, Florida 32548
(904) 243-6424

1314 Buford Street, N.W.
Huntsville, Alabama 35801
(205) 539-4411
TWX: 810-726-2114

P.O. Box 513
Orlando, Florida 32802
(305) 425-5505
TWX: 810-850-0146

1682 Weymouth Court
Tucker, Georgia 30084
(404) 939-1674

1108 Burke Street, N.W.
Winston-Salem, N.C. 27101
(919) 725-5384 (919) 725-5385

Crane & Egert Corporation

146 Meacham Avenue
Elmont, New York 11003
(516) 488-2100
TWX: 510-223-0417

Electronic Marketing Associates

11501 Huff Court
Kensington, Maryland 20795
(301) 881-5300 (301) 744-7700
TWX: 710-825-9645

210 Goddard Boulevard, Room 100
King of Prussia, Pennsylvania 19406
(215) 265-1600 (215) 248-5050
TWX: 510-660-3130

KLM Associates

1 Nouvelle Park
New Hartford, New York 13413
(315) 735-8525
TWX: 510-242-1286

401 South Main St.
N. Syracuse, New York 13212
(315) 458-6214

39 Saginaw Drive
Rochester New York 14623
(716) 442-0820
TWX: 510-253-6106

Southern International Sales Corp.

GPO Box 1896
San Juan, Puerto Rico 00936
(809) 722-0863
TELEX: 365384

Teledyne Philbrick

Allied Drive at Route 128
Dedham, Massachusetts 02026
(617)329-1600
TWX: 710-348-6726

MIDWEST REGION

Carter, McCormic & Peirce, Inc.

23995 Freeway Park Drive
Farmington, Michigan 48024
(313) 477-7700
TWX: 810-242-2986

21380 Lorain Road
Cleveland, Ohio 44126
(216) 333-5650
TWX: 810-421-8304

P.O. Box 1472
Dayton, Ohio 45414
(513) 278-5873
TWX: 810-459-1613

201 Penn Center Blvd.
Room 217
Pittsburgh, Pennsylvania 15235
(412) 824-3760

Data Electronics Company, Inc.

5505 North Menard Avenue
Chicago, Illinois 60630
(312) 774-1452

821 Second Avenue North
Minneapolis, Minnesota 55405
(612) 377-8383

McGraw Engineering

Box 511
Florissant, Missouri 63033
(314) 831-0342

512 McDonald
Leavenworth, Kansas 66408
(913)651-2929

WESTERN REGION

Barnhill Five, Inc.

1170 South Sheridan Blvd.
Denver, Colorado 80226
(303) 934-5505
TWX: 910-931-2685

537 East Osborn Road
Suite 4
Phoenix, Arizona 85012
(602) 263-1250
TWX: 910-951-1595

1410D Wyoming Street
Albuquerque, New Mexico 87112
(505)299-7658
TWX: 910-989-1650

Pactron Systems

133 Mookua Street
Kailua, Oahu, Hawaii 96734
(808) 261-1224

Tech-Ser., Inc.

2435 North Naomi
Burbank, California 91504
(213) 846-9631
TWX: 910-498-2709

800 San Antonio Road
Palo Alto, California 94303
(415)326-6400
TWX: 910-373-1762

P. O. Box 10544
San Diego, California 92110
(714) 222-1121

Data Marketing Associates

3925 C Dacoma Street
Houston, Texas 77018
(713) 686-9627
TWX: 910-881-2569

10050 Monroe Drive
Dallas, Texas 75229
(214) 358-4643
TWX: 910-861-4300

Teledyne Philbrick

P.O. Box 58463
Houston, Texas 77058
(713) 488-5941

Post Office Box 349
Canoga Park, California 91305
(213) 887-8873
TWX: 910-494-2765

DISTRIBUTORS

INTERMARK ELECTRONICS, INC.

100 Industrial Road
San Carlos, California 94077
Tel: 415-592-1641
TWX: 910-376-4899

7933 Clairemont Mesa Blvd.
San Diego, California 92111
Tel: 714-279-5200
TWX: 910-335-1238

17192 Gillette Street
Santa Ana, California 29705
Tel: (213)537-4664
714-540-1322
TWX: 910-595-1583

7110 Gerald Avenue
Van Nuys, California 91406
Tel: 213-782-0362
TWX: 910-495-2005

445 East Second Street
Salt Lake City, Utah 84111
(801)359-0531

621 South Michigan Street
Seattle, Washington 98108
Tel: 206-767-3160
TWX: 910-444-2054

2600 West 2nd Avenue
Denver, Colorado 80219
Tel: 303-936-8284
TWX: 910-931-0501

1318 E. Princess Drive
Tempe, Arizona 85281
(602)968-3489
TWX: 910-950-1940

4673 Main Street
Vancouver 10, British Columbia
(604)873-2477

TELEDYNE PHILBRICK

Allied Drive at Route 128, Dedham, Massachusetts 02026
Tel: (617)329-1600 TWX: (710)348-6726 Telex: 92-4439

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Dedham, Mass.

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Allied Drive at Route 128
Dedham, Massachusetts 02026 USA

My product interest is — I am presently using:

- ☐ Linear Modules — Type ____ Qty ____
- ☐ Nonlinear Function Modules — Type ____ Qty ____
- ☐ Data Conversion Modules — Type ____ Qty ____
- ☐ Instrumentation — Type ____ Qty ____
- ☐ Power Modules — Type ____ Qty ____

Please send more information on Model(s) _____

My Application is _____

_____

My interest is ☐ Immediate ☐ Future

☐ Information Only

- ☐ I would like to evaluate Model _____
- ☐ Please have field engineer call
- ☐ Please add my name to your mailing list
- ☐ Please send the *New Lightning Empiricist*
- ☐ Please send the *Applications Manual for Computing Amplifiers* (price $5.00)

Name _____

Title _____

Company _____

Dept. _____

Address _____

City _____ State _____ Zip _____

Telephone _____ Ext. _____

My product interest is — I am presently using:

- ☐ Linear Modules — Type ____ Qty ____
- ☐ Nonlinear Function Modules — Type ____ Qty ____
- ☐ Data Conversion Modules — Type ____ Qty ____
- ☐ Instrumentation — Type ____ Qty ____
- ☐ Power Modules — Type ____ Qty ____

Please send more information on Model(s) _____

My Application is _____

_____

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Dept. _____

Address _____

City _____ State _____ Zip _____

Telephone _____ Ext. _____