PHILBRICK RESEARCHES, INC.
ALLIED DRIVE at ROUTE 128, DEDHAM, MASSACHUSETTS 02026

MODEL PP65AU

Economy Grade, All Silicon Solid State Differential Operational Amplifier

Model PP65AU is a cast epoxy differential operational amplifier of modest performance. Electrically, its performance is similar to that of Model P65AU, with the further advantage that voltage trim adjustments, if deemed necessary, are tailored by the user to his own needs and applied externally.

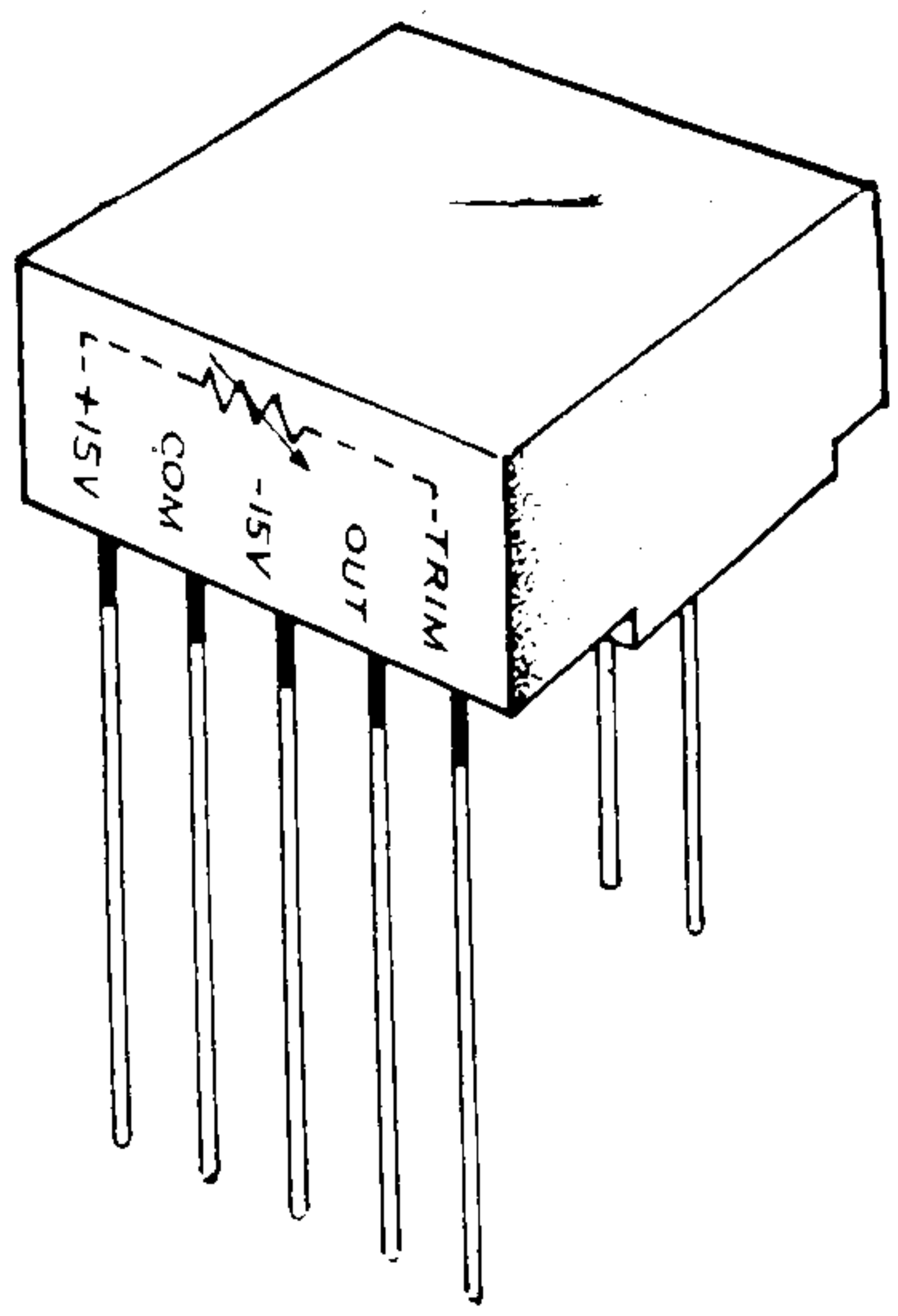
Over the temperature range 10°C to 60°C, it is identical in performance to Model PP65A. ~~It can be operated at temperatures between -25°C and +85°C and stored at temperatures~~ between -55°C and +85°C. When used over the extended temperature range, the economy units differ from the premium units by a factor of 2 in voltage gain and a factor of 1.5 for the input offset current.

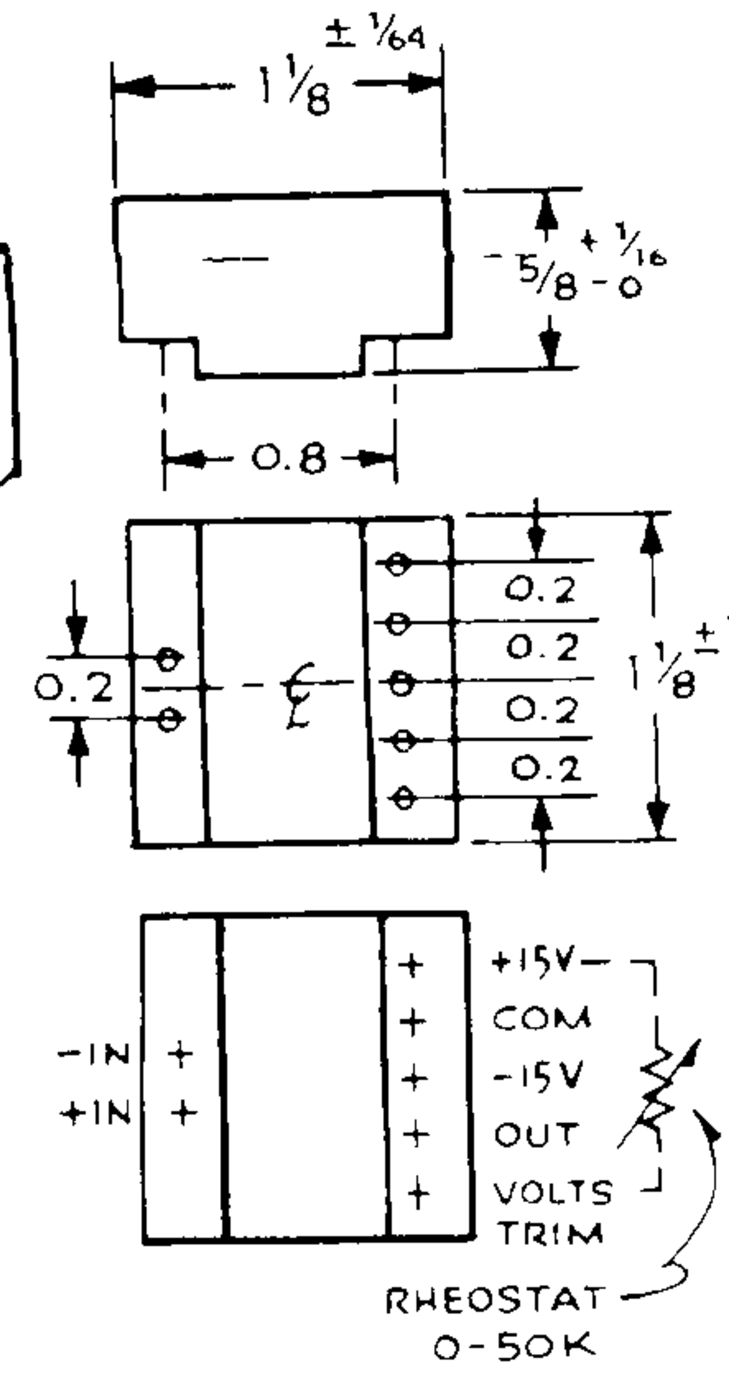
The use of silicon transistors encapsulated in highly moisture resistant silicone plastic instead of hermetically-sealed cases permits performance identical to that of the military/industrial amplifiers at a greatly reduced price.

Applications are in measurement, computing, control, model building, and active mathematics. Its durability, small size, low power drain and convenient form for permanent installation make it equally at home in portable devices or large systems, in the laboratory or industry.

Physically, the following features are salient:

- Size ~~is nominally~~ 1 1/8" x 1 1/8" x 5/8" H above chassis or board.
- Volume is less than 0.9 cubic inches.
- Weight is less than 1.1 oz. installed.
- Circuit is permanently embedded in epoxy compound for durability.
- Nickel clad copper leads, .030 Dia., on standard 0.1 inch grid spacing permit printed circuit board mounting and permanent solder connection.
- Step is provided to eliminate moisture buildup, permit minor lead adjustment, and provide above-chassis test points.





BOTTOM VIEW

Detailed electrical characteristics are as follows:

VOLTAGE GAIN (dc open-loop):	
+25°C (5 kΩ output load)	20,000 (min.)
+25°C (100 kΩ output load)	80,000 (min.)
-25°C to +85°C (5 kΩ output load)	5,000 (min.)
RESPONSE (as inverting amplifier):	
Small signal unity gain-bandwidth	1.3 Mc/s (min.)
Large signal (full output)	10 kc/s (min.)
Rate limit	0.6 V/μsec.
INPUT VOLTAGE RANGE:	
Both inputs	±10 V
Between inputs	5 V (abs. max.)
Common mode rejection ratio (dc)	1000:1 (min.)
INPUT IMPEDANCE:	
Between inputs (dc)	150 kΩ min.)
Common mode (dc)	20 MΩ min.)

INPUT VOLTAGE OFFSET:	
Initial offset voltage	Externally adjustable to zero
Vs. temperature (+10°C to +60°C)	1.5 mV (max.)
Vs. temperature (-25°C to +85°C)	6 mV (max.)
Vs. time (per day)	50 μV (typical)
Vs. time (per half hour)	10 μV (typical)
INPUT CURRENT OFFSET:	
Initial offset (+25°C)	500 nA (max.)
Vs. temperature (+10°C to +60°C)	200 nA (max.)
Vs. temperature (-25°C to +85°C)	1.2 μA (max.)
Vs. time (per day)	20 nA (typical)
Vs. time (per half hour)	2 nA (typical)
OUTPUT (5kΩ load):	
Voltage	±11 volts (min.)
Current	±2.2 mA
POWER REQUIREMENT:	
Quiescent	±5.5 mA at ±15 V
Full output (at ±11 V, 5 kΩ load - typical)	+7.7 mA at +15 V
(add 10% for maximum requirement).	-5.5 mA at -15 V

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INSTALLATION NOTES

Compensation and Biasing

The amplifier's input transistors have uncompensated base current of less than 0.5 microampere flowing toward the amplifier's plus and minus signal input terminals at 25°C and zero common mode voltage. In addition, the sum of the forward drops of the base-emitter junctions ~~of the input transistors~~ is in general not equal to zero.

The total effect of these current and voltage static errors at the output is expressed as follows: (Refer to Figures below.)

$$e = (e_b - e_a - i_1R_0)\ (1 + \frac{R_2}{R_1}) + i_2R_2$$

Evidently there is a value of R_0 that will, for a given combination of R_2, R_1, $e_b - e_a$, i_1, and i_2 precisely compensate e to zero. In general, however, it is better to adjust the errors having the greatest contribution to output error to as low a value as necessary.

The voltage error, $e_b - e_a$, is adjusted by setting a 50kΩ rheostat connected between the TRIM terminal and +15 volts for zero output under the conditions of line 1 of the table. If a nominal millivolt trim is adequate, simply connect the resistance value closest to that given in the chart for a given amplifier. The TRIM terminal can be connected directly to +15 volts without causing more than a few millivolts of error, but it should never be left free.

The current bias errors at the two inputs are compensated by supplying currents equal to the base currents from the +15 volts supply. If R_0 is to be zero, it is, of course, unnecessary to compensate i_1. The nominal values given in the chart appropriate to each amplifier may be used; but if it is desired that they be accurately adjustable or if they are deemed too high in resistance, a 10 to 22 megohm resistor connected between the input and a low impedance voltage divider between +15 volts and ground may be used. The net input error currents are adjusted as closely as possible to zero by the procedure of lines 4 and 5.

Temperature Variations

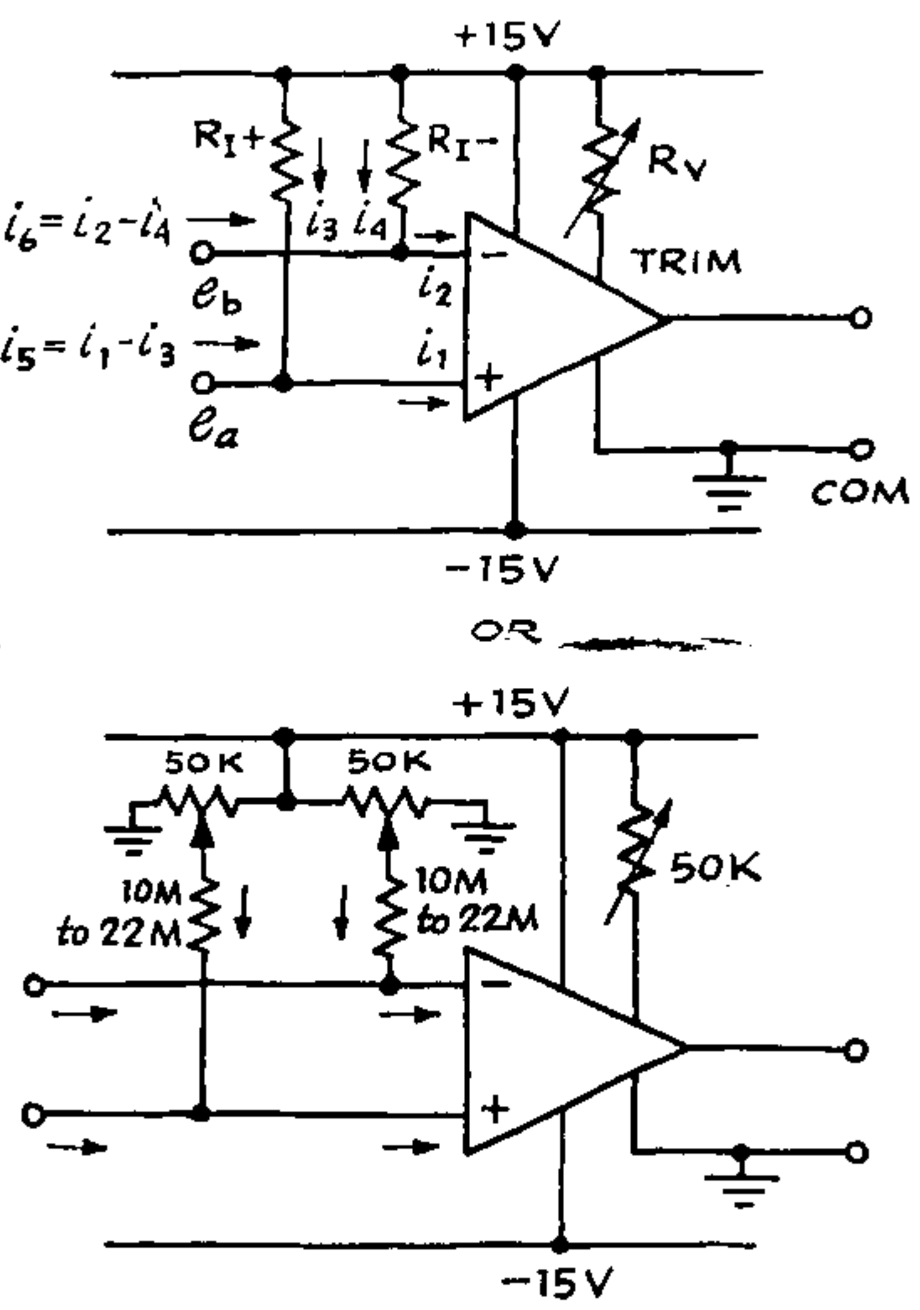
As ambient temperature changes, i_1 and i_2 tend to decrease with increasing temperature. Total variation over the -25°C to +85°C range is typically between 200 nanoamperes at +85°C and 750 at -25°C. The greatest change is at low temperatures; but near room temperature (25°C) the temperature coefficient is usually less than 5 nanoamperes per degree Centigrade. At the same time, $e_b - e_a$ can either increase or decrease with temperature. Total variation over the -25°C to +85°C range is specified to never exceed 6 millivolts, the median being at about 2.5 millivolts. Voltage offset is roughly proportional to temperature, with the temperature coefficient in the vicinity of room temperature being about 20 microvolts per degree centigrade.

If we differentiate the currents and voltages in the above equation with respect to temperature, we obtain

$$\frac{de}{d\theta} = \frac{d(e_b - e_a)}{d\theta} - R_0\frac{di_1}{d\theta})\ (1 + \frac{R_2}{R_1}) + \frac{di_2}{d\theta}R_2$$

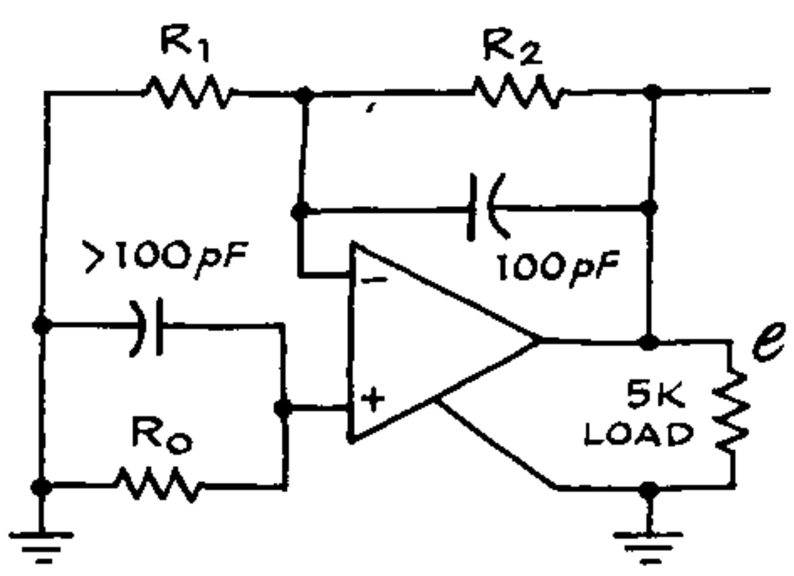
If for a given amplifier, the temperature coefficients, $\frac{d(e_b - e_a)}{d\theta}$, $\frac{di_1}{d\theta}$, and $\frac{di_2}{d\theta}$ are all constant or linearly related to one another over a given range of temperature, it should be possible to choose a value of R_0 that will produce effectively zero change in static error over that range.

CONNECTIONS



OFFSET TRIM ____ K
+I TRIM ______ M
—I TRIM ______ M

TEST CIRCUIT



		MEASUREMENT			
		R_0	R_1	R_2	FORMULA
① $e_b - e_a$ =	VOLTAGE OFFSET ADJUST R_V FOR $e \to 0$ AT OP. TEMP & COMM. MODE VOLTAGE	100Ω	100Ω	10K	$e_b - e_a = \frac{e}{101}$
② i_1 = +IN	UNCOMPENSATED BASE CURRENT ($< +10^{-6}a$)	10^7Ω	∞	0	$i_1 = -10^{-7}e$
③ i_2 = −IN	UNCOMPENSATED BASE CURRENT ($< +10^{-6}a$)	0 Ω	∞	10^7Ω	$i_2 = 10^{-7}e$
④ i_3 = +IN	BASE CURRENT COMPENSATION ADJUST R_I+ (or POT) FOR $e \to 0$ AT OP. TEMP & COMM. MODE VOLT.	10^7Ω	∞	0	$i_5 = -10^{-7}e$
⑤ i_4 = −IN	BASE CURRENT COMPENSATION ADJUST R_I- (or POT) FOR $e \to 0$ AT OP. TEMP & COMM. MODE VOLT.	0 Ω	∞	10^7Ω	$i_6 = 10^{-7}e$
~~⑥ FACTORY~~	~~TEMPERATURE DRIFT TEST~~ (-25°C to +85°C) <10mv REFERRED TO INPUT	~~1K*~~	~~1K~~	~~100K~~	~~$\Delta e < 0.6V$~~

Preliminary data

Models P65AU and PP65AU Utility grade economical all-silicon operational amplifiers

Models P65AU and PP65AU are two new operational amplifier types identical in physical configuration and connections to their military/industrial grade counterparts, Models P65A and PP65A. They are also identical in performance over the temperature range 0°C to 60°C, can be operated at temperatures between -25°C and +85°C and stored at temperatures between -55°C and +85°C. When used over the extended temperature range, the economy units differ from the premium units by a factor of 2 in voltage gain and input offset current.

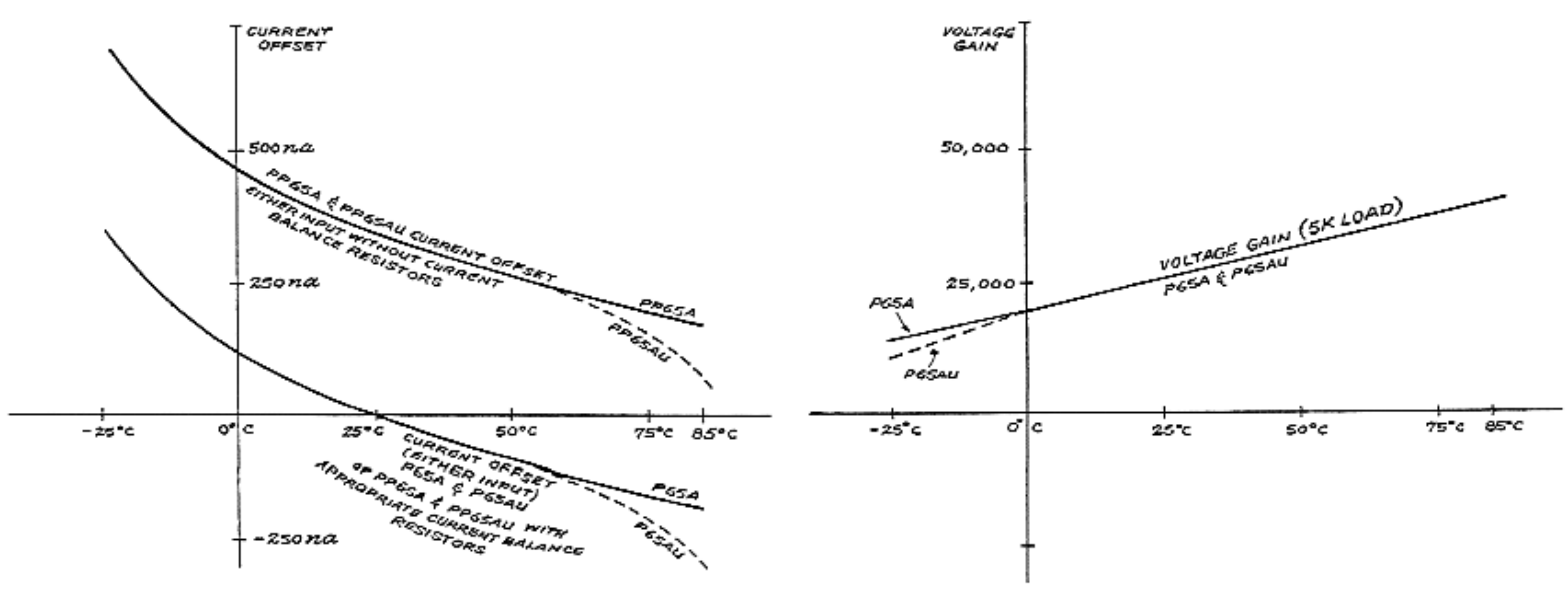
The use of silicon transistors encapsulated in highly moisture resistant silicone plastic instead of hermetically sealed cases permits performance identical to that of military/industrial amplifiers at a greatly reduced price.

We employ our usual careful techniques of selecting and grading components and in assembling the new utility amplifiers. Long experience in the manufacture of P65A-type amplifiers permits us to guarantee identical performance of the new utility line with a program of selective testing that approaches in rigor the tests applied to the premium units.*

Our new two-year warranty now applies to the economical utility amplifiers, as well as to the rest of our line. This warranty, which has been unofficially maintained for many years, is now official.

TWO-YEAR WARRANTY

All Philbrick products are warranted against defects in materials and workmanship for a period of two (2) years after date of shipment. Our obligation is limited to replacing, repairing, or adjusting products (except tubes) which prove to be defective during the warranty period. We are not liable for consequential damages.



TYPICAL PERFORMANCE VS. TEMPERATURE ··· P65A, PP65A COMPARED TO P65AU, PP65AU

Comparative Characteristics	Model P65A	Model P65AU
Voltage gain (dc open loop):		
+25°C, rated load, minimum	20,000	20,000
-25°C, minimum	10,000	5,000
Response (open loop, as inverter,+25°C):		
Full output (worst case)	10 kcps	10 kcps
Small signal unity gain-bandwidth	1.3 Mcps	1.3 Mcps
Gain at 1.0 Mcps, typical	1.3	1.3
Rated output (-25°C to +85°C):		
Voltage	±11 volts	±11 volts
Current	±2.2 ma	±2.2 ma
Load	5 K	5 K
Input voltage offset:		
Adjustment	Built-in	Built-in
Max. vs. temperature (-25°C to +85°C)	6 mv	6 mv
Max. vs. temperature (+10°C to +60°C)	1.5 mv	1.5 mv
Vs. time (per day) typical	50 microvolts	50 microvolts
Vs. time (half hour) typical	10 microvolts	10 microvolts
Narrow-band noise (p-p)	2 microvolts	2 microvolts
Input current offset (either input):		
+25°C worst case	100 nanoamperes	100 nanoamperes
Max. vs. temperature (-25°C to +85°C)	0.8 microamperes	1.2 microamperes
Max. vs. temperature (+10°C to +60°C)	200 nanoamperes	200 nanoamperes
Vs. time (per day) typical	20 nanoamperes	20 nanoamperes
Vs. time (half hour) typical	2 nanoamperes	2 nanoamperes
Narrow-band noise (p-p)	0.5 nanoamperes	0.5 nanoamperes
Input impedance (+25°C), resistive component:		
Between inputs	150 K	150 K
Either input to common	More than 20M	More than 20M
Common mode:		
Input range	±10 volts	±10 volts
Maximum dc error (+25°C)	±10 millivolts	±10 millivolts
Temperature range (in °C):		
Maximum operating	-25 to +85	-25 to +85
Maximum storage	-55 to +85	-55 to +85
Typical operating (best performance vs. reliability)	0 to +60°C	0 to +60°C
Power requirements (+25°C)	±15 volts	±15 volts
Current at+15 volts (quiescent)	5.5 milliamperes	5.5 milliamperes
Current at+15 volts (full load)	8 milliamperes	8 milliamperes
Current at -15 volts (quiescent)	5.5 milliamperes	5.5 milliamperes
Current at -15 volts (full load)	5 milliamperes	5 milliamperes
Outline dimensions and connections:	P	P
Price (subject to change):		
1 - 4	$85	$35
5 - 14	83	35
15 - 24	80	34.50
25 and up	**	**

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