# HA-2600, HA-2602, HA-2605

## 12MHz, High Input Impedance Operational Amplifiers

November 1996

### Features

- Bandwidth . . . . . 12MHz
- High Input Impedance . . . . . 500MΩ
- Low Input Bias Current . . . . . 1nA
- Low Input Offset Current . . . . . 1nA
- Low Input Offset Voltage . . . . . 0.5mV
- High Gain . . . . . 150kV/V
- Slew Rate . . . . . 7V/µs
- Output Short Circuit Protection
- Unity Gain Stable

### Applications

- Video Amplifier
- Pulse Amplifier
- Audio Amplifiers and Filters
- High-Q Active Filters
- High-Speed Comparators
- Low Distortion Oscillators

### Ordering Information

| PART NUMBER (BRAND) | TEMP. RANGE (°C) | PACKAGE | PKG. NO. |
|---|---|---|---|
| HA2-2600-2 | -55 to 125 | 8 Pin Metal Can | T8.C |
| HA2-2602-2 | -55 to 125 | 8 Pin Metal Can | T8.C |
| HA2-2605-5 | 0 to 75 | 8 Pin Metal Can | T8.C |
| HA3-2605-5 | 0 to 75 | 8 Ld PDIP | E8.3 |
| HA7-2600-2 | -55 to 125 | 8 Ld CERDIP | F8.3A |
| HA7-2602-2 | -55 to 125 | 8 Ld CERDIP | F8.3A |
| HA7-2605-5 | 0 to 75 | 8 Ld CERDIP | F8.3A |
| HA9P2605-5 (H26055) | 0 to 75 | 8 Ld SOIC | M8.15 |

### Description

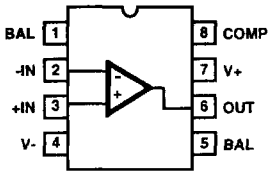
HA-2600/2602/2605 are internally compensated bipolar operational amplifiers that feature very high input impedance (500MΩ, HA-2600) coupled with wideband AC performance. The high resistance of the input stage is complemented by low offset voltage (0.5mV, HA-2600) and low bias and offset current (1nA, HA-2600) to facilitate accurate signal processing. Input offset can be reduced further by means of an external nulling potentiometer. 12MHz unity gain-bandwidth, 7V/µs slew rate and 150kV/V open-loop gain enables HA-2600/2602/2605 to perform high-gain amplification of fast, wideband signals. These dynamic characteristics, coupled with fast settling times, make these amplifiers ideally suited to pulse amplification designs as well as high frequency (e.g. video) applications. The frequency response of the amplifier can be tailored to exact design requirements by means of an external bandwidth control capacitor.

In addition to its application in pulse and video amplifier designs, HA-2600/2602/2605 are particularly suited to other high performance designs such as high-gain low distortion audio amplifiers, high-Q and wideband active filters and high-speed comparators. For more information, please refer to Application Note AN515.

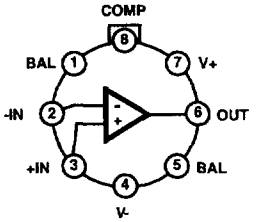
The HA-2600 and HA-2602 are offered as /883 Military Grade; product and data sheets are available upon request.

### Pinouts

**HA-2600/02 (CERDIP)**
**HA-2605 (PDIP, CERDIP, SOIC)**
TOP VIEW




**HA-2600/02/05**
**(METAL CAN)**
TOP VIEW




3 OPERATIONAL AMPLIFIERS



File Number **2902.2**

## Absolute Maximum Ratings

Supply Voltage Between V+ and V- Terminals . . . . . 45V
Differential Input Voltage . . . . . 12V
Peak Output Current . . . . . Full Short Circuit Protection

## Operating Conditions

Temperature Range
HA-2600/HA-2602-2 . . . . . -55°C to 125°C
HA-2605-5 . . . . . 0°C to 75°C
HA-2605-9 . . . . . -40°C to 85°C

## Thermal Information

| Thermal Resistance (Typical, Note 1) | $\theta_{JA}$ (°C/W) | $\theta_{JC}$ (°C/W) |
|---|---|---|
| Metal Can Package | 165 | 80 |
| PDIP Package | 96 | N/A |
| CERDIP Package | 135 | 50 |
| SOIC Package | 157 | N/A |

Maximum Junction Temperature (Hermetic Package) . . . . . 175°C
Maximum Junction Temperature (Plastic Package) . . . . . 150°C
Maximum Storage Temperature Range . . . . . -65°C to 150°C
Maximum Lead Temperature (Soldering 10s) . . . . . 300°C
(SOIC - Lead Tips Only)

*CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.*

NOTE:

1. $\theta_{JA}$ is measured with the component mounted on an evaluation PC board in free air.

## Electrical Specifications $V_{SUPPLY}$ = ±15V, Unless Otherwise Specified

| PARAMETER | TEMP. (°C) | HA-2600-2 | | | HA-2602-2 | | | HA-2605-9 HA-2605-5 | | | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| **INPUT CHARACTERISTICS** | | | | | | | | | | | |
| Offset Voltage | 25 | - | 0.5 | 4 | - | 3 | 5 | - | 3 | 5 | mV |
| | Full | - | 2 | 6 | - | - | 7 | - | - | 7 | mV |
| Average Offset Voltage Drift | Full | - | 5 | - | - | 5 | - | - | 5 | - | µV/°C |
| Bias Current (Note 2) | 25 | - | 1 | 10 | - | 15 | 25 | - | 5 | 25 | nA |
| | Full | - | 10 | 30 | - | - | 60 | - | - | 40 | nA |
| Offset Current (Note 2) | 25 | - | 1 | 10 | - | 5 | 25 | - | 5 | 25 | nA |
| | Full | - | 5 | 30 | - | - | 60 | - | - | 40 | nA |
| Differential Input Resistance (Note 12) | 25 | 100 | 500 | - | 40 | 300 | - | 40 | 300 | - | MΩ |
| Input Noise Voltage Density (f = 1kHz) | 25 | - | 11 | - | - | 11 | - | - | 11 | - | nV/√Hz |
| Input Noise Current Density (f = 1kHz) | 25 | - | 0.16 | - | - | 0.16 | - | - | 0.16 | - | pA/√Hz |
| Common Mode Range | Full | ±11 | ±12 | - | ±11 | ±12 | - | ±11 | ±12 | - | V |
| **TRANSFER CHARACTERISTICS** | | | | | | | | | | | |
| Large Signal Voltage Gain (Notes 3, 6) | 25 | 100 | 150 | - | 80 | 150 | - | 80 | 150 | - | kV/V |
| | Full | 70 | - | - | 60 | - | - | 70 | - | - | kV/V |
| Common Mode Rejection Ratio (Note 4) | Full | 80 | 100 | - | 74 | 100 | - | 74 | 100 | - | dB |
| Minimum Stable Gain | 25 | 1 | - | - | 1 | - | - | 1 | - | - | V/V |
| Gain Bandwidth Product (Note 5) | 25 | - | 12 | - | - | 12 | - | - | 12 | - | MHz |
| **OUTPUT CHARACTERISTICS** | | | | | | | | | | | |
| Output Voltage Swing (Note 3) | Full | ±10 | ±12 | - | ±10 | ±12 | - | ±10 | ±12 | - | V |
| Output Current (Note 6) | 25 | ±15 | ±22 | - | ±10 | ±18 | - | ±10 | ±18 | - | mA |
| Full Power Bandwidth (Notes 6, 13) | 25 | 50 | 75 | - | 50 | 75 | - | 50 | 75 | - | kHz |
| **TRANSIENT RESPONSE** (Note 10) | | | | | | | | | | | |
| Rise Time (Notes 3, 7, 8, 9) | 25 | - | 30 | 60 | - | 30 | 60 | - | 30 | 60 | ns |
| Overshoot (Notes 3, 7, 8, 9) | 25 | - | 25 | 40 | - | 25 | 40 | - | 25 | 40 | % |
| Slew Rate (Notes 3, 7, 9, 14) | 25 | ±4 | ±7 | - | ±4 | ±7 | - | ±4 | ±7 | - | V/µs |
| Settling Time (Notes 3, 7, 15) | 25 | - | 1.5 | - | - | 1.5 | - | - | 1.5 | - | µs |

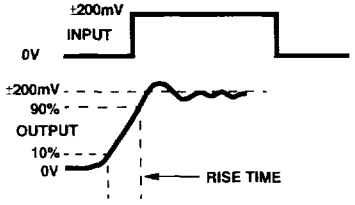
**Electrical Specifications** $V_{SUPPLY}$ = ±15V, Unless Otherwise Specified **(Continued)**

| PARAMETER | TEMP. (°C) | HA-2600-2 | | | HA-2602-2 | | | HA-2605-9 HA-2605-5 | | | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| **POWER SUPPLY CHARACTERISTICS** | | | | | | | | | | | |
| Supply Current | 25 | - | 3 | 3.7 | - | 3 | 4 | - | 3 | 4 | mA |
| Power Supply Rejection Ratio (Note 11) | Full | 80 | 90 | - | 74 | 90 | - | 74 | 90 | - | dB |

NOTES:

2. Typical and minimum specifications for -9 are identical to those of -5. All maximum specifications for -9 are identical to those of -5 except for Full Temperature Bias and Offset Currents, which are 70nA Max
3. $R_L$ = 2kΩ.
4. $V_{CM}$ = ±10V.
5. $V_{OUT}$ < 90mV.
6. $V_{OUT}$ = ±10V.
7. $C_L$ = 100pF.
8. $V_{OUT}$ = ±200mV.
9. $A_V$ = +1.
10. See Transient Response Test Circuits and Waveforms.
11. $\Delta V_S$ = ±5V.
12. This parameter value guaranteed by design calculations.
13. Full Power Bandwidth guaranteed by slew rate measurement: $FPBW = \frac{\text{Slew Rate}}{2\pi V_{PEAK}}$.
14. $V_{OUT}$ = ±5V
15. Settling time is characterized at $A_V$ = -1 to 0.1% of a 10V step.

## Test Circuits and Waveforms




NOTE: Measured on both positive and negative transitions from 0V to +200mV and 0V to -200mV at the output.

**FIGURE 1. TRANSIENT RESPONSE**

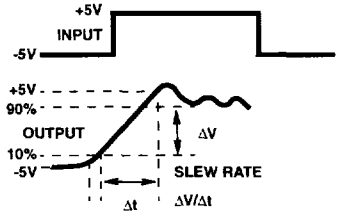



**FIGURE 2. SLEW RATE**

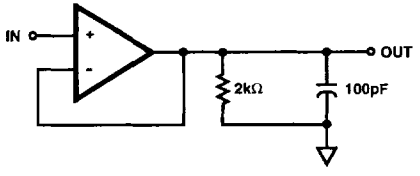
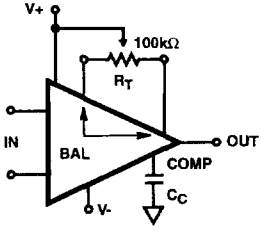


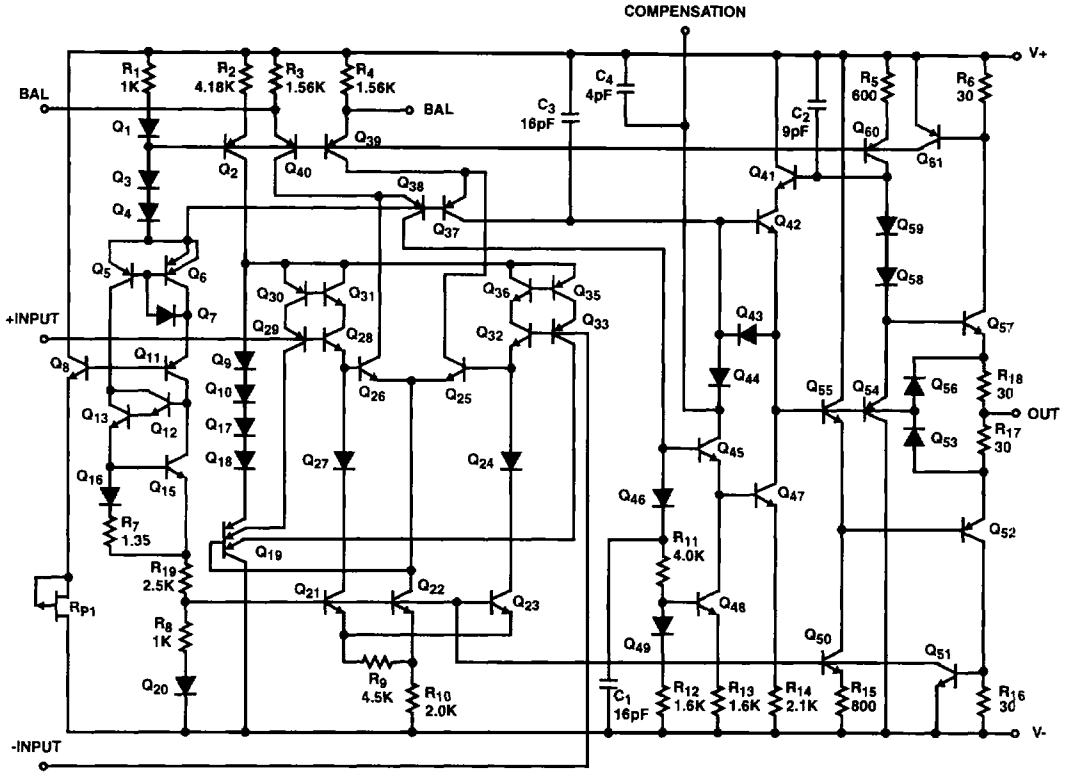

**FIGURE 3. SLEW RATE AND TRANSIENT RESPONSE TEST CIRCUIT**



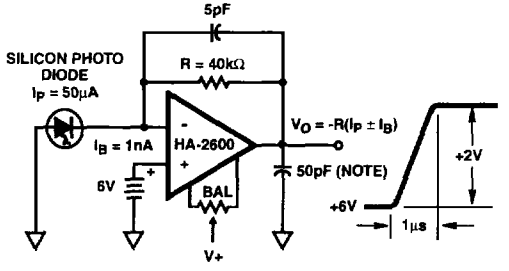

NOTE: Tested offset adjustment range is $|V_{OS}| + 1mV|$ minimum referred to output. Typical ranges are ±10mV with $R_T$ = 100kΩ.

**FIGURE 4. SUGGESTED $V_{OS}$ ADJUSTMENT AND COMPENSATION HOOK UP**

## Schematic Diagram

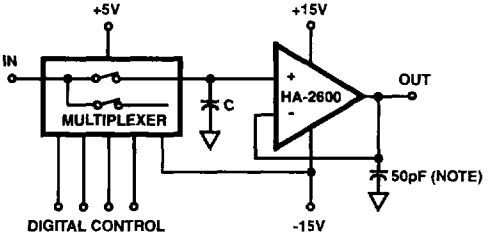



## Typical Applications




FEATURES:

1. Constant cell voltage.
2. Minimum bias current error.




$$\text{DRIFT RATE} = \frac{I_{BIAS}}{C}$$

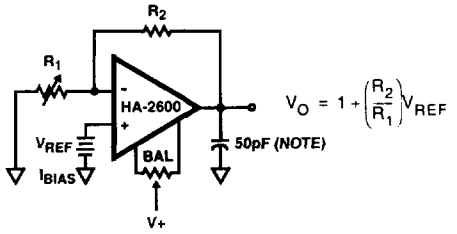
If C = 1000pF
Then DRIFT = 0.01V/µs (Max)

NOTE: A small load capacitance is recommended in all applications where practical to prevent possible high frequency oscillations resulting from external wiring parasitics. Capacitance up to 100pF has negligible effect on the bandwidth or slew rate.

**FIGURE 5. PHOTO CURRENT TO VOLTAGE CONVERTER**

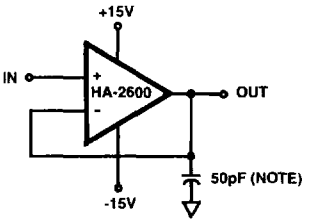
**FIGURE 6. SAMPLE AND HOLD**

## Typical Applications (Continued)




FEATURES:
1. Minimum bias current in reference cell.
2. Short Circuit Protection.

FIGURE 7. REFERENCE VOLTAGE AMPLIFIER




FEATURES
1. $Z_{IN} = 10^{12}\Omega$ (Min).
2. $Z_{OUT} = 0.01\Omega$ (Max), B.W. = 12MHz (Typ).
3. Slew Rate = 4V/µs (Min), Output Swing = ±10V (Min) to 50kHz.

FIGURE 8. VOLTAGE FOLLOWER

NOTE: A small load capacitance is recommended in all applications where practical to prevent possible high frequency oscillations resulting from external wiring parasitics. Capacitance up to 100pF has negligible effect on the bandwidth or slew rate.

## Typical Performance Curves $V_S = \pm15V$, $T_A = 25^oC$, Unless Otherwise Specified

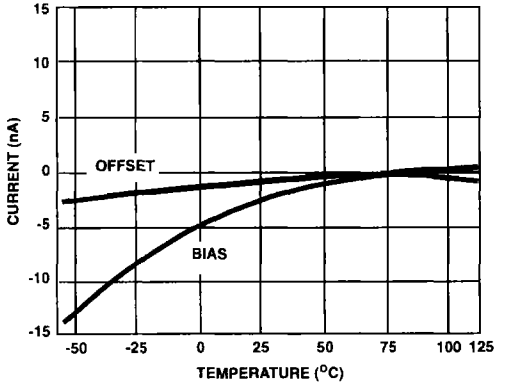



FIGURE 9. INPUT BIAS CURRENT AND OFFSET CURRENT vs TEMPERATURE

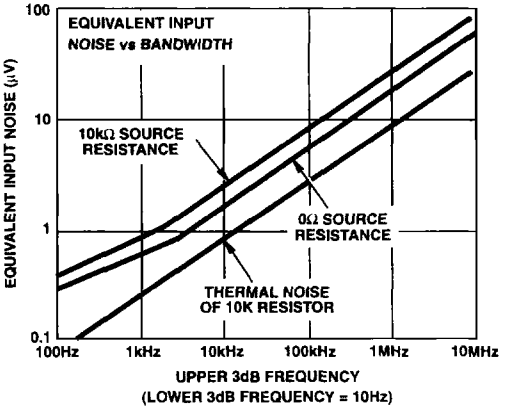



FIGURE 10. BROADBAND NOISE CHARACTERISTICS

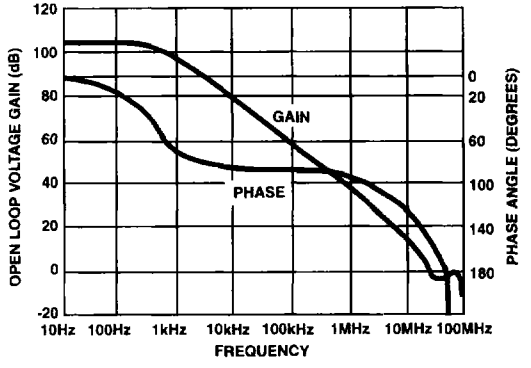



FIGURE 11. OPEN LOOP FREQUENCY RESPONSE

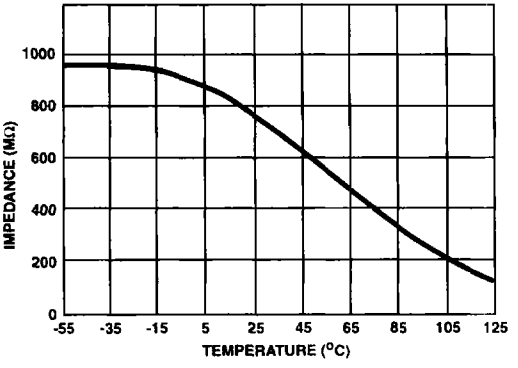



FIGURE 12. INPUT IMPEDANCE vs TEMPERATURE (100Hz)

## Typical Performance Curves $V_S = \pm15V$, $T_A = 25^oC$, Unless Otherwise Specified (Continued)

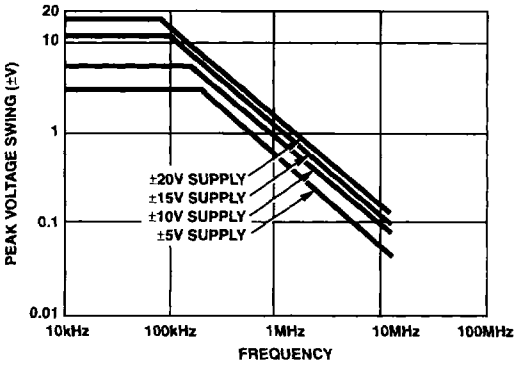
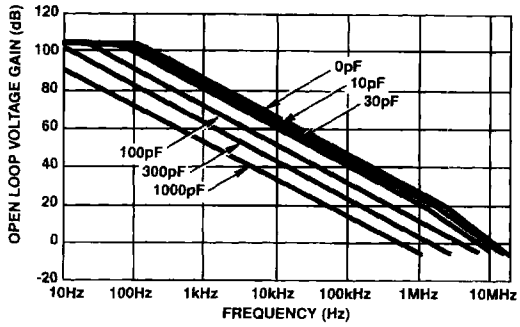



FIGURE 13. OUTPUT VOLTAGE SWING vs FREQUENCY




NOTE: External compensation components are not required for stability, but may be added to reduce bandwidth if desired. If External Compensation is used, also connect 100pF capacitor from output to ground.

FIGURE 14. OPEN LOOP FREQUENCY RESPONSE FOR VARIOUS VALUES OF CAPACITORS FROM COMPENSATION PIN TO GROUND

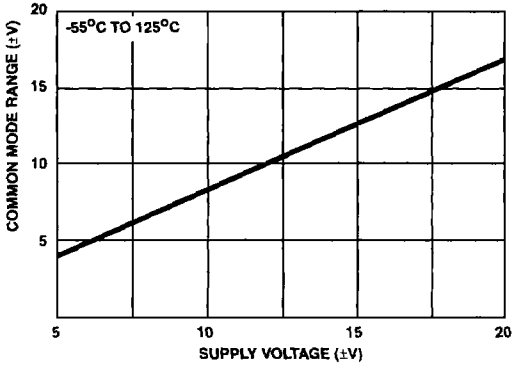



FIGURE 15. COMMON MODE VOLTAGE RANGE vs SUPPLY VOLTAGE

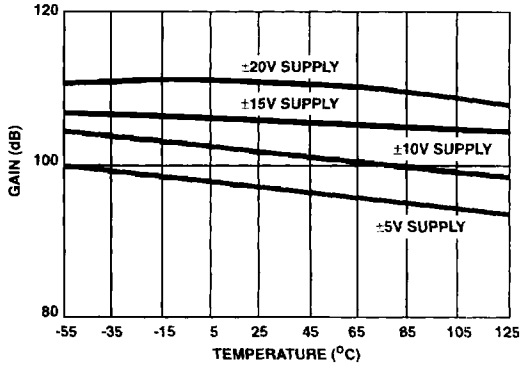



FIGURE 16. OPEN LOOP VOLTAGE GAIN vs TEMPERATURE

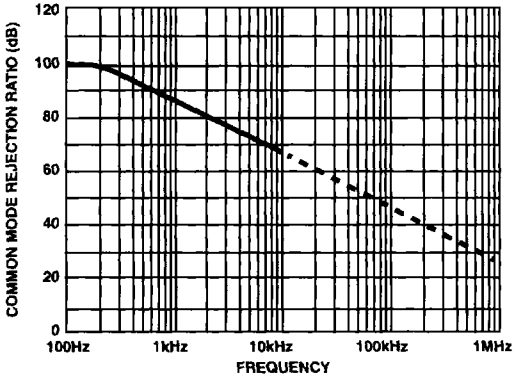



FIGURE 17. COMMON MODE REJECTION RATIO vs FREQUENCY

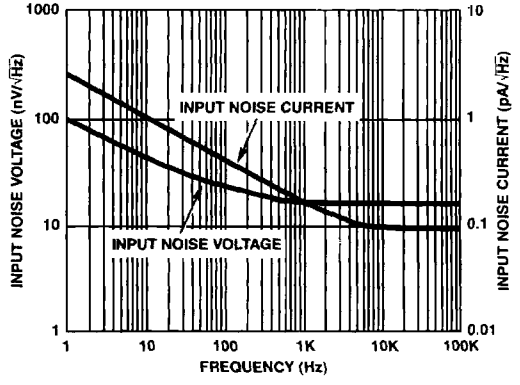



FIGURE 18. NOISE DENSITY vs FREQUENCY

## Die Characteristics

**DIE DIMENSIONS:**

69 mils x 56 mils x 19 mils
1750µm x 1420µm x 483µm

**METALLIZATION:**

Type: Al, 1% Cu
Thickness: 16kÅ ±2kÅ

**SUBSTRATE POTENTIAL (Powered Up):**

Unbiased

**PASSIVATION:**

Type: Nitride ($Si_3N_4$) over Silox ($SiO_2$, 5% Phos.)
Silox Thickness: 12kÅ ±2kÅ
Nitride Thickness: 3.5kÅ ±1.5kÅ

**TRANSISTOR COUNT:**

140

**PROCESS:**

Bipolar Dielectric Isolation

## Metallization Mask Layout

**HA-2600, HA-2602, HA-2605**