# Low-voltage high performance mixer FM IF system NE/SA606

T-74-11-01

## DESCRIPTION

The NE/SA606 is a low-voltage high performance monolithic FM IF system incorporating a mixer/oscillator, two limiting intermediate frequency amplifiers, quadrature detector, logarithmic received signal strength indicator (RSSI), voltage regulator and audio and RSSI op amps. The NE/SA606 is available in 20-lead dual-in-line plastic, 20-lead SOL (surface-mounted small outline large package) and 20-lead SSOP (shrink small outline package).

The NE606 was designed for portable communication applications and will function down to 2.7V. The RF section is similar to the famous NE605. The audio and RSSI outputs have amplifiers with access to the feedback path. This enables the designer to level adjust the outputs or add filtering.

## FEATURES

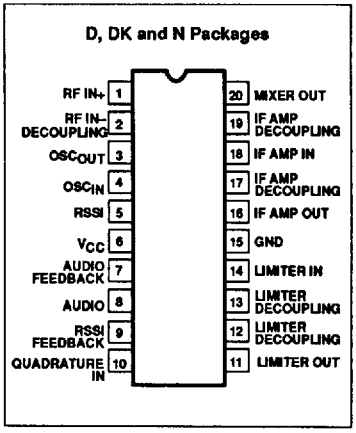
- Low power consumption: 3.5mA typical at 3V
- Mixer input to >150MHz
- Mixer conversion power gain of 17dB at 45MHz
- XTAL oscillator effective to 150MHz (L.C. oscillator or external oscillator can be used at higher frequencies)
- 102dB of IF Amp/Limiter gain
- 2MHz limiter small signal bandwidth
- Temperature compensated logarithmic Received Signal Strength Indicator (RSSI) with a 90dB dynamic range
- Low external component count; suitable for crystal/ceramic/LC filters
- Excellent sensitivity: 0.31μV into 50Ω matching network for 12dB SINAD (Signal to Noise and Distortion ratio) for 1kHz tone with RF at 45MHz and IF at 455kHz
- SA606 meets cellular radio specifications
- Audio output internal op amp
- RSSI output internal op amp
- Internal op amps with rail-to-rail outputs
- ESD protection: Human Body Model 2kV
  Robot Model 200V

## APPLICATIONS

- Portable cellular radio FM IF
- Cordless phones
- Wireless systems
- RF level meter
- Spectrum analyzer
- Instrumentation
- FSK and ASK data receivers
- Log amps
- Portable high performance communication receiver
- Single conversion VHF receivers

## PIN CONFIGURATION

D, DK and N Packages




## ORDERING INFORMATION

| DESCRIPTION | TEMPERATURE RANGE | ORDER CODE |
|---|---|---|
| 20-Pin Plastic DIP | 0 to +70°C | NE606N |
| 20-Pin Plastic SOL (Surface-mount) | 0 to +70°C | NE606D |
| 20-Pin Plastic SSOP (Surface-mount) | 0 to +70°C | NE606DK |
| 20-Pin Plastic DIP | -40 to +85°C | SA606N |
| 20-Pin Plastic SOL (Surface-mount) | -40 to +85°C | SA606D |
| 20-Pin Plastic SSOP (Surface-mount) | -40 to +85°C | SA606DK |

## ABSOLUTE MAXIMUM RATINGS

| SYMBOL | PARAMETER | | RATING | UNITS |
|---|---|---|---|---|
| $V_{CC}$ | Single supply voltage | | 7 | V |
| $T_{STG}$ | Storage temperature range | | –65 to +150 | °C |
| $T_A$ | Operating ambient temperature range | NE606 | 0 to +70 | °C |
| | | SA606 | –40 to +85 | °C |
| $\theta_{JA}$ | Thermal impedance | D package<br>DK package<br>N package | 90<br>117<br>75 | °C/W |

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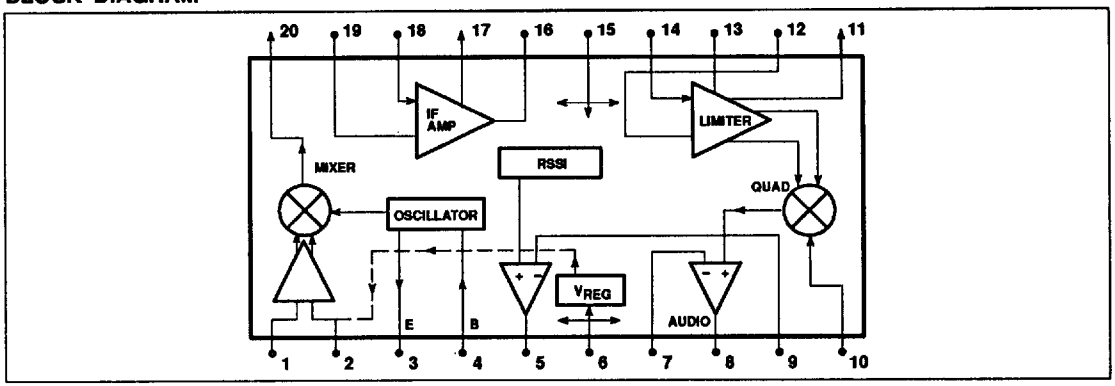
## BLOCK DIAGRAM




## DC ELECTRICAL CHARACTERISTICS

$V_{CC}$ = +3V, $T_A$ = 25°C; unless otherwise stated.

| SYMBOL | PARAMETER | TEST CONDITIONS | LIMITS NE/SA606 | | | UNITS |
|---|---|---|---|---|---|---|
| | | | MIN | TYP | MAX | |
| $V_{CC}$ | Power supply voltage range | | 2.7 | | 7.0 | V |
| $I_{CC}$ | DC current drain | | | 3.5 | 4.2 | mA |

## AC ELECTRICAL CHARACTERISTICS

$T_A$ = 25°C; $V_{CC}$ = +3V, unless otherwise stated. RF frequency = 45MHz + 14.5dBV RF input step-up; IF frequency = 455kHz; R17 = 2.4kΩ and R18 = 3.3kΩ; RF level = –45dBm; FM modulation = 1kHz with ±8kHz peak deviation. Audio output with de-emphasis filter and C-message weighted filter. Test circuit Figure 1. The parameters listed below are tested using automatic test equipment to assure consistent electrical characterristics. The limits do not represent the ultimate performance limits of the device. Use of an optimized RF layout will improve many of the listed parameters.

| SYMBOL | PARAMETER | TEST CONDITIONS | LIMITS NE/SA606 | | | UNITS |
|---|---|---|---|---|---|---|
| | | | MIN | TYP | MAX | |
| **Mixer/Osc section (ext LO = 220mV$_{RMS}$)** | | | | | | |
| $f_{IN}$ | Input signal frequency | | | 150 | | MHz |
| $f_{OSC}$ | Crystal oscillator frequency | | | 150 | | MHz |
| | Noise figure at 45MHz | | | 6.2 | | dB |
| | Third–order input intercept point (50Ω source) | f1 = 45.0; f2 = 45.06MHz Input RF level = –52dBm | | –9 | | dBm |
| | Conversion power gain | Matched 14.5dBV step–up | 13.5 | 17 | 19.5 | dB |
| | | 50Ω source | | +2.5 | | dB |
| | RF input resistance | Single–ended input | | 8 | | kΩ |
| | RF input capacitance | | | 3.0 | 4.0 | pF |
| | Mixer output resistance | (Pin 20) | 1.25 | 1.5 | | kΩ |
| **IF section** | | | | | | |
| | IF amp gain | 50Ω source | | 44 | | dB |
| | Limiter gain | 50Ω source | | 58 | | dB |
| | Input limiting –3dB, $R_{17a}$ = 2.4k, $R_{17b}$ = 3.3k | Test at Pin 18 | | –109 | | dBm |
| | AM rejection | 80% AM 1kHz | | 45 | | dB |
| | Audio level | Gain of two (2kΩ AC load) | 70 | 120 | 160 | mV |
| | SINAD sensitivity | IF level –110dBm | | 17 | | dB |

# Low-voltage high performance mixer FM IF system NE/SA606

## AC ELECTRICAL CHARACTERISTICS (Continued)

| SYMBOL | PARAMETER | TEST CONDITIONS | LIMITS | | | UNITS |
|---|---|---|---|---|---|---|
| | | | NE606 | | | |
| | | | MIN | TYP | MAX | |
| THD | Total harmonic distortion | | –35 | –50 | | dB |
| S/N | Signal–to–noise ratio | No modulation for noise | | 62 | | dB |
| | IF RSSI output, $R_9$ = 2kΩ[1] | IF level = –118dBm | | 0.3 | .80 | V |
| | | IF level = –68dBm | .70 | 1.1 | 1.80 | V |
| | | IF level = –23dBm | 1.20 | 1.8 | 2.50 | V |
| | RSSI range | | | 90 | | dB |
| | RSSI accuracy | | | ±1.5 | | dB |
| | IF input impedance | Pin 18 | 1.3 | 1.5 | | kΩ |
| | IF output impedance | Pin 16 | | 0.3 | | kΩ |
| | Limiter input impedance | Pin 14 | 1.3 | 1.5 | | kΩ |
| | Limiter output impedance | Pin 11 | | 0.3 | | kΩ |
| | Limiter output voltage | Pin 11 | | 130 | | $mV_{RMS}$ |
| **RF/IF section (Int LO)** | | | | | | |
| | Audio level | 3V = $V_{CC}$, RF level = –27dBm | | 120 | | $mV_{RMS}$ |
| | System RSSI output | 3V = $V_{CC}$, RF level = –27dBm | | 2.2 | | V |
| | System SINAD sensitivity | RF level = –117dBm | | 12 | | dB |

**NOTE:**
1. The generator source impedance is 50Ω, but the NE/SA606 input impedance at Pin 18 is 1500Ω. As a result, IF level refers to the actual signal that enters the NE/SA606 input (Pin 18) which is about 21dB less than the "available power" at the generator.

## CIRCUIT DESCRIPTION

The NE/SA606 is an IF signal processing system suitable for second IF systems with input frequency as high as 150MHz. The bandwidth of the IF amplifier and limiter is at least 2MHz with 90dB of gain. The gain/bandwidth distribution is optimized for 455kHz, 1.5kΩ source applications. The overall system is well-suited to battery operation as well as high performance and high quality products of all types.

The input stage is a Gilbert cell mixer with oscillator. Typical mixer characteristics include a noise figure of 6.2dB, conversion gain of 17dB, and input third-order intercept of –9dBm. The oscillator will operate in excess of 200MHz in L/C tank configurations. Hartley or Colpitts circuits can be used up to 100MHz for xtal configurations. Butler oscillators are recommended for xtal configurations up to 150MHz.

The output impedance of the mixer is a 1.5kΩ resistor permitting direct connection to a 455kHz ceramic filter. The input resistance of the limiting IF amplifiers is also 1.5kΩ. With most 455kHz ceramic filters and many crystal filters, no impedance matching network is necessary. The IF amplifier has 43dB of gain and 5.5MHz bandwidth. The IF limiter has 60dB of gain and 4.5MHz bandwidth. To achieve optimum linearity of the log signal strength indicator, there must be a 12dB(v) insertion loss between the first and second IF stages. If the IF filter or interstage network does not cause 12dB(v) insertion loss, a fixed or variable resistor or an L pad for simultaneous loss and impedance matching can be added between the first IF output (Pin 16) and the interstage network. The overall gain will then be 90dB with 2MHz bandwidth.

The signal from the second limiting amplifier goes to a Gilbert cell quadrature detector. One port of the Gilbert cell is internally driven by the IF. The other output of the IF is AC-coupled to a tuned quadrature network. This signal, which now has a 90° phase relationship to the internal signal, drives the other port of the multiplier cell.

The demodulated output of the quadrature drives an internal op amp. This op amp can be configured as a unity gain buffer, or for simultaneous gain, filtering, and 2nd-order temperature compensation if needed. It can drive an AC load as low as 5kΩ with a rail-to-rail output.

A log signal strength completes the circuitry. The output range is greater than 90dB and is temperature compensated. This log signal strength indicator exceeds the criteria for AMPs or TACs cellular telephone. This signal drives an internal op amp. The op amp is capable of rail-to-rail output. It can be used for gain, filtering, or 2nd-order temperature compensation of the RSSI, if needed.

NOTE: $dB(v) = 20\log V_{OUT}/V_{IN}$

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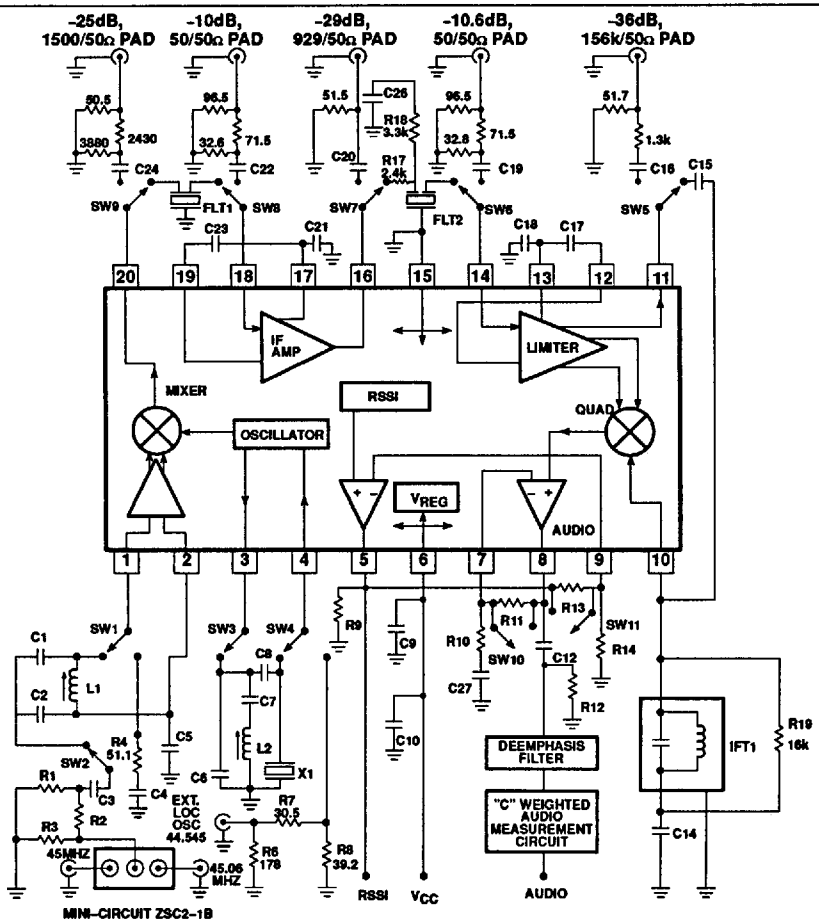
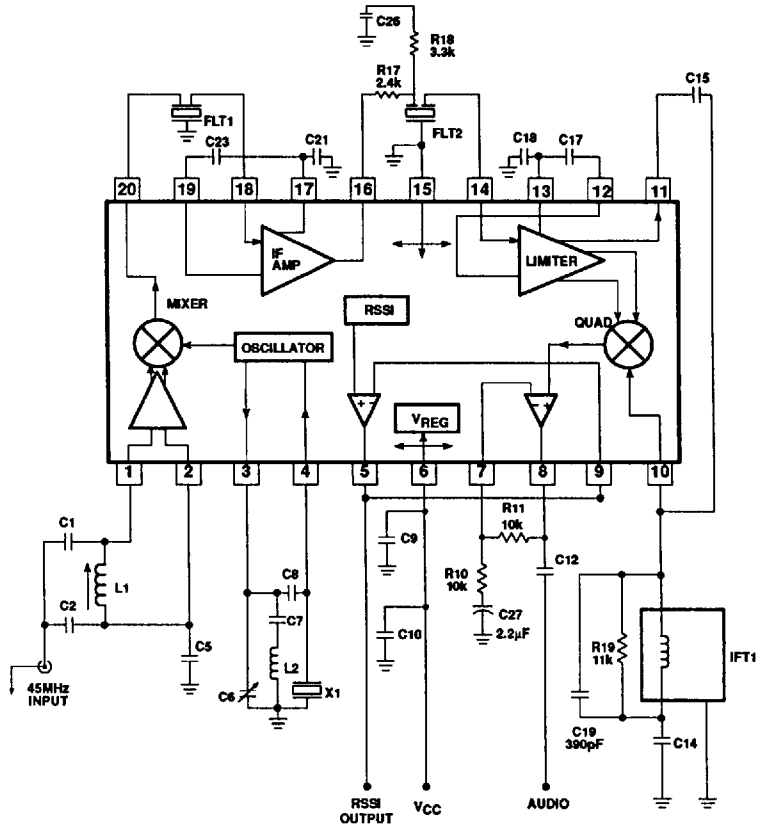



**Automatic Test Circuit Component List**

| | | | |
|---|---|---|---|
| C1 | 100pF NPO Ceramic | C27 | 2.2µF ±10% Monolithic Ceramic |
| C2 | 390pF NPO Ceramic | Flt 1 | Ceramic Filter Murata SFG455A3 or equiv |
| C5 | 100nF ±10% Monolithic Ceramic | Flt 2 | Ceramic Filter Murata SFG455A3 or equiv |
| C6 | 22pF NPO Ceramic | IFT 1 | 455kHz (Ce = 180pF) Toko RMC–2A6597H |
| C7 | 1nF Ceramic | L1 | 147–160nH Coilcraft UNI–10/142–04J08S |
| C8 | 10.0pF NPO Ceramic | L2 | 0.8µH nominal |
| C9 | 100nF ±10% Monolithic Ceramic | | Toko 292CNS–T1038Z |
| C10 | 10µF Tantalum (minimum) * | X1 | 44.545MHz Crystal ICM4712701 |
| C12 | 2.2µF | R9 | 2kΩ ±1% 1/4W Metal Film |
| C14 | 100nF ±10% Monolithic Ceramic | R10 | 10kΩ ±1% |
| C15 | 10pF NPO Ceramic | R11 | 10kΩ ±1% |
| C17 | 100nF ±10% Monolithic Ceramic | R12 | 2kΩ ±1% |
| C18 | 100nF ±10% Monolithic Ceramic | R13 | 20kΩ ±1% |
| C21 | 100nF ±10% Monolithic Ceramic | R14 | 10kΩ ±1% |
| C23 | 100nF ±10% Monolithic Ceramic | R17 | 2.4kΩ ±5% 1/4W Carbon Composition |
| C25 | 100nF ±10% Monolithic Ceramic | R18 | 3.3kΩ |
| C26 | 100nF ±10% Monolithic Ceramic | R19 | 16kΩ |

*NOTE: This value can be reduced when a battery is the power source.

Figure 1. NE/SA606 45MHz Test Circuit (Relays as shown)




**NE606D/DK Demo Board**
**Application Component List**

| | |
|---|---|
| C1 | 51pF NPO Ceramic |
| C2 | 220pF NPO Ceramic |
| C5 | 100nF ±10% Monolithic Ceramic |
| C6 | 5-30pF trim cap |
| C7 | 1nF Ceramic |
| C8 | 10.0pF NPO Ceramic |
| C9 | 100nF ±10% Monolithic Ceramic |
| C10 | 10µF Tantalum (minimum) * |
| C12 | 2.2µF ±10% Tantalum |
| C14 | 100nF ±10% Monolithic Ceramic |
| C15 | 10pF NPO Ceramic |
| C17 | 100nF ±10% Monolithic Ceramic |
| C18 | 100nF ±10% Monolithic Ceramic |
| C19 | 390pF ±10% Monolithic Ceramic |
| C21 | 100nF ±10% Monolithic Ceramic |
| C23 | 100nF ±10% Monolithic Ceramic |
| C26 | 100nF ±10% Monolithic Ceramic |
| C27 | 2.2µF Tantalum |
| Flt 1 | Ceramic Filter Murata SFG455A3 or equiv |
| Flt 2 | Ceramic Filter Murata SFG455A3 or equiv |
| IFT 1 | 330µH TOKO 303LN-1130 |
| L1 | .33µH TOKO SCB-1320Z |
| L2 | 1.2µH |
| X1 | 44.545MHz Crystal ICM4712701 |
| R5 | Not Used in Application Board (see Note 8, pg 8) |
| R10 | 8.2k ±5% 1/4W Carbon Composition |
| R11 | 10k ±5% 1/4W Carbon Composition |
| R17 | 2.4k ±5% 1/4W Carbon Composition |
| R18 | 3.3k ±5% 1/4W Carbon Composition |
| R19 | 11k ±5% 1/4W Carbon Composition |

* NOTE: This value can be reduced when a battery is the power source.

**Figure 2. NE/SA606 45MHz Application Circuit**

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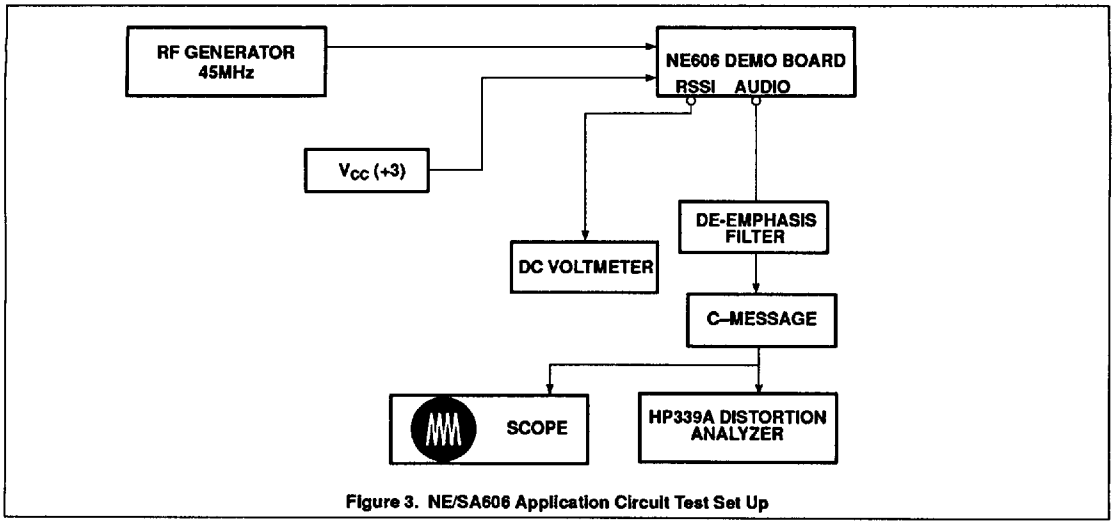



**Figure 3. NE/SA606 Application Circuit Test Set Up**

**NOTES:**

1. C-message: The C-message and de-emphasis filter combination has a peak gain of 10 for accurate measurements. Without the gain, the measurements may be affected by the noise of the scope and HP339 analyzer. The de-emphasis filter has a fixed -6dB/Octave slope between 300Hz and 3kHz.
2. Ceramic filters: The ceramic filters can be 30kHz SFG455A3s made by Murata which have 30kHz IF bandwidth (they come in blue), or 16kHz CFU455Ds, also made by Murata (they come in black). All of our specifications and testing are done with the more wideband filter.
3. RF generator: Set your RF generator at 45.000MHz, use a 1kHz modulation frequency and a 6kHz deviation if you use 16kHz filters, or 8kHz if you use 30kHz filters.
4. Sensitivity: The measured typical sensitivity for 12dB SINAD should be 0.35µV or –116dBm at the RF input.
5. Layout: The layout is very critical in the performance of the receiver. We highly recommend our demo board layout.
6. RSSI: The smallest RSSI voltage (i.e., when no RF input is present and the input is terminated) is a measure of the quality of the layout and design. If the lowest RSSI voltage is 500mV or higher, it means the receiver is in regenerative mode. In that case, the receiver sensitivity will be worse than expected.
7. Supply bypass and shielding: All of the inductors, the quad tank, and their shield must be grounded. A 10-15µF or higher value tantalum capacitor on the supply line is essential. A low frequency ESR screening test on this capacitor will ensure consistent good sensitivity in production. A 0.1µF bypass capacitor on the supply pin, and grounded near the 44.545MHz oscillator improves sensitivity by 2-3dB.
8. R5 can be used to bias the oscillator transistor at a higher current for operation above 45MHz. Recommended value is 10kΩ.

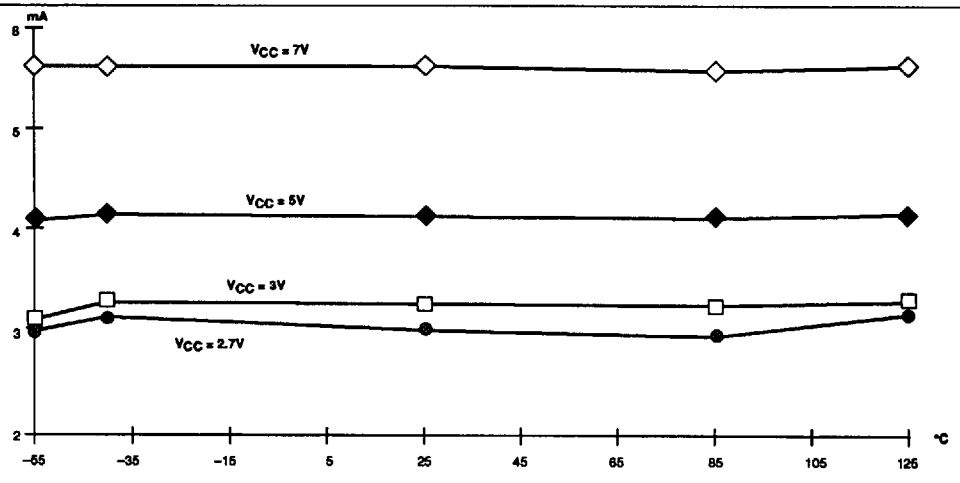



Figure 4. $I_{CC}$ vs Temperature

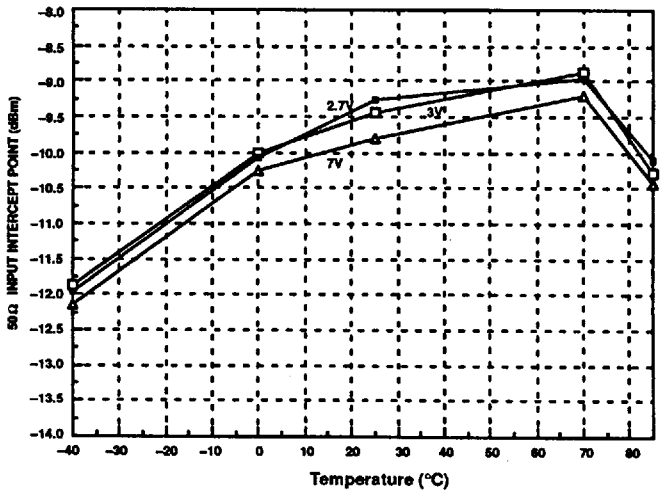



Figure 5. Third Order Intercept Point vs Supply Voltage

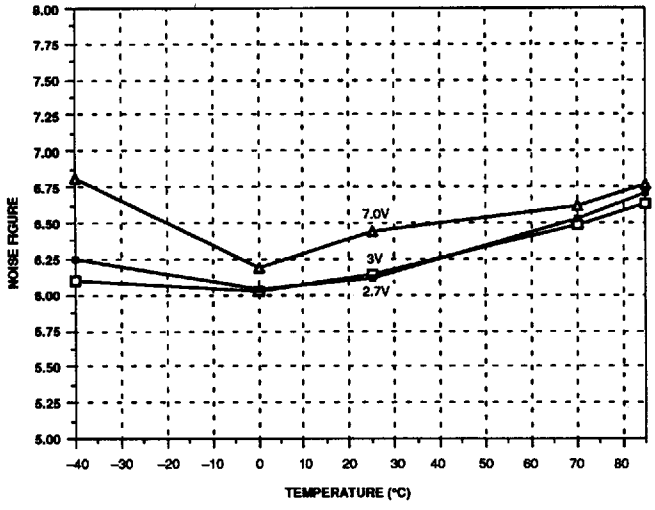



**Figure 6. Mixer Noise Figure vs Supply Voltage**

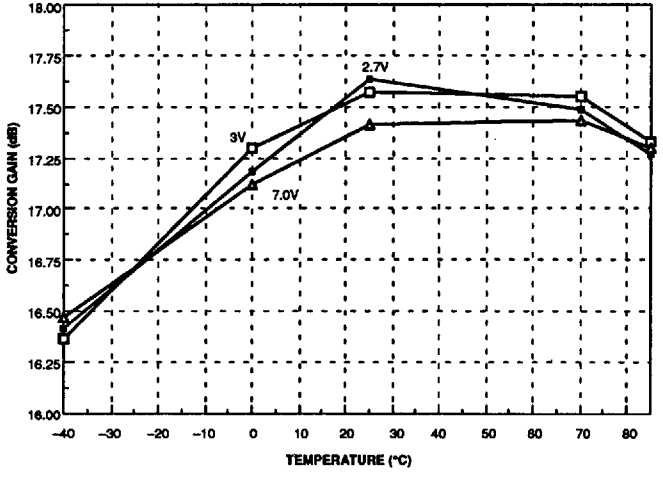



**Figure 7. Conversion Gain vs Supply Voltage**

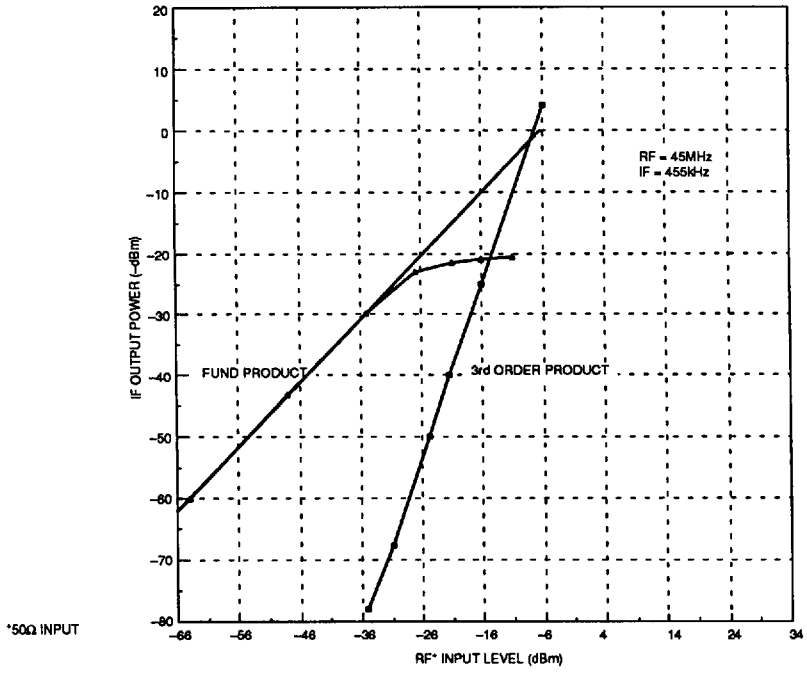



**Figure 8. Mixer Third Order Intercept and Compression**

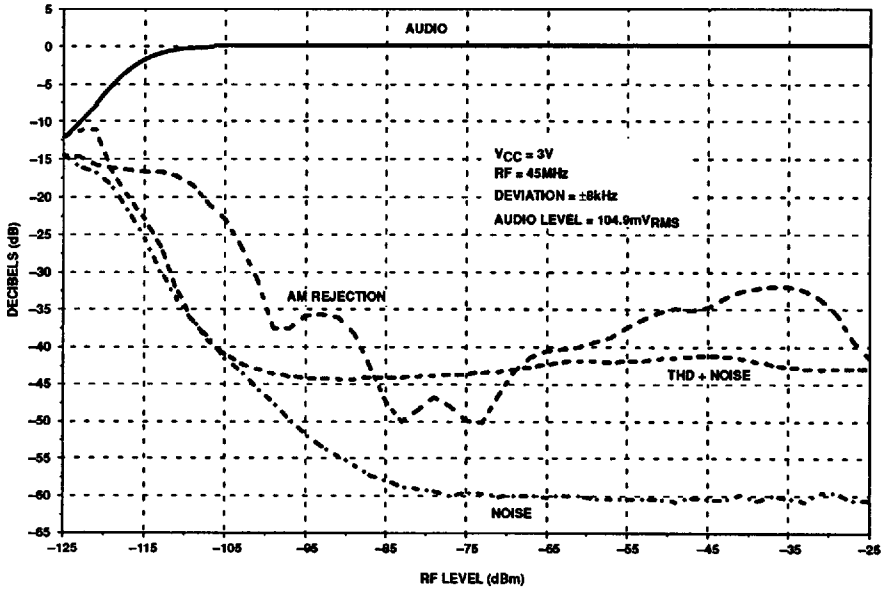



Figure 9. Sensitivity vs RF Level (–40°C)

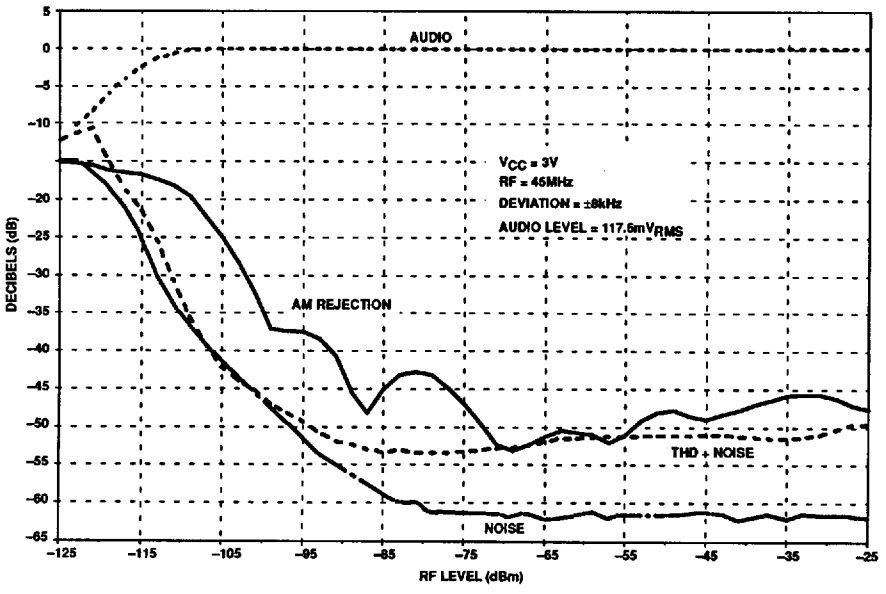



Figure 10. Sensitivity vs RF Level (+25°C)

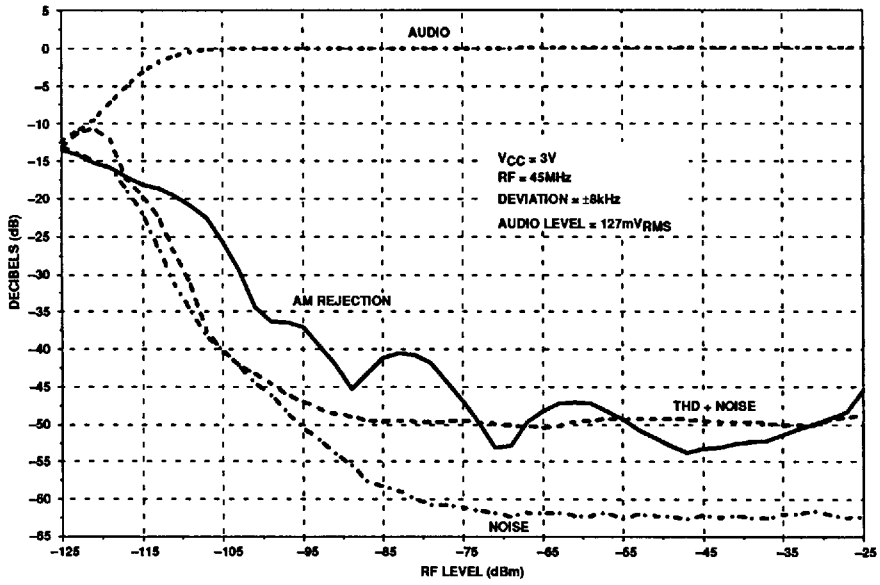



**Figure 11. Sensitivity vs RF Level (Temperature 85°C)**

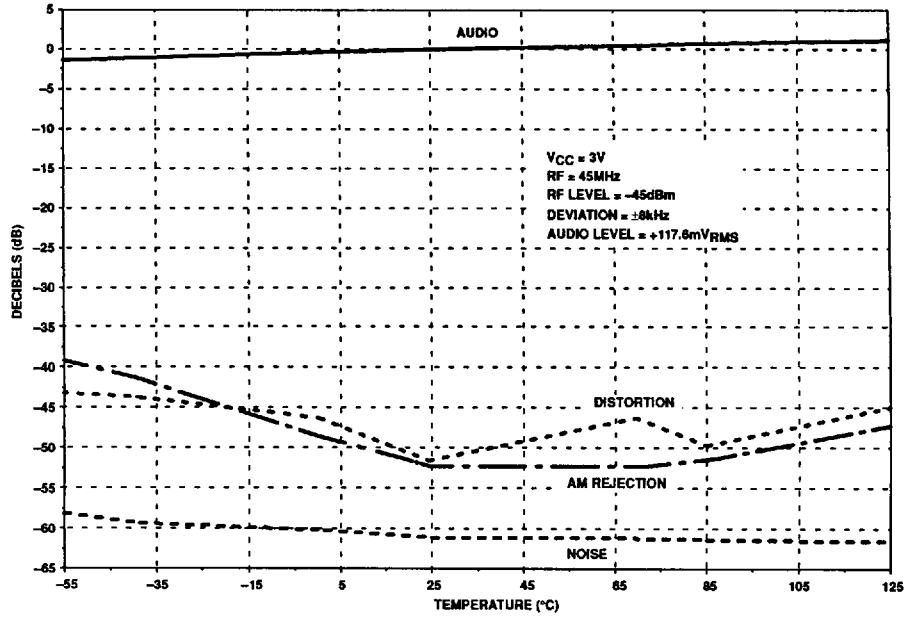



**Figure 12. Relative Audio Level, Distortion, AM Rejection and Noise vs Temperature**

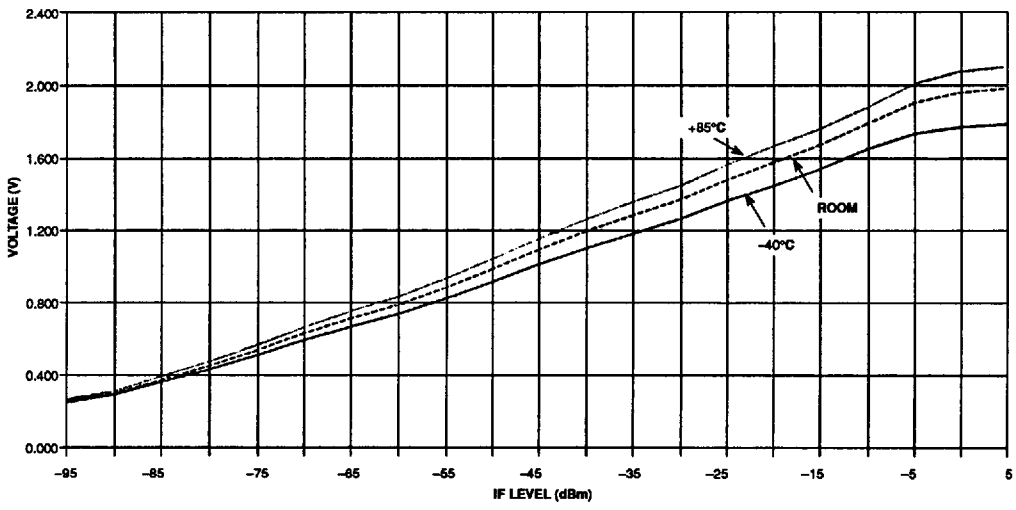



Figure 13. RSSI (455kHz IF @ 3V)

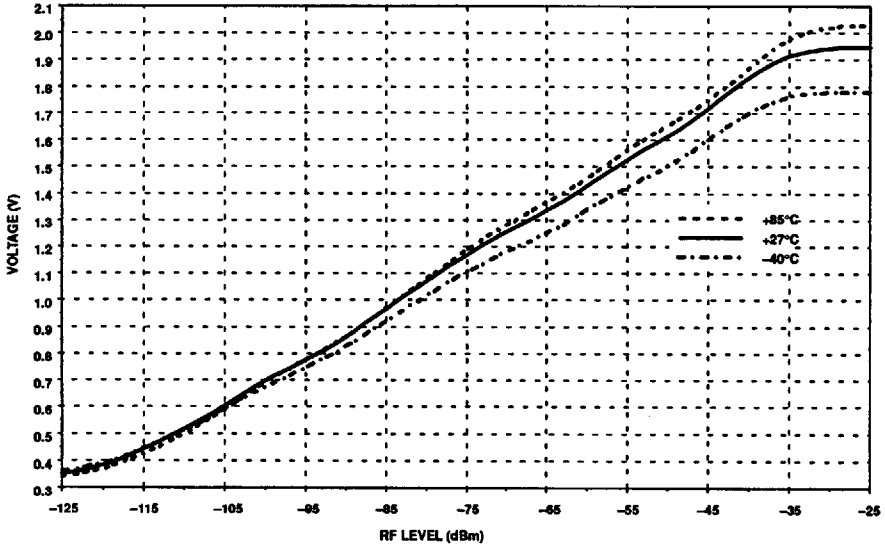



Figure 14. RSSI vs RF Level and Temperature - $V_{CC}$ = 3V

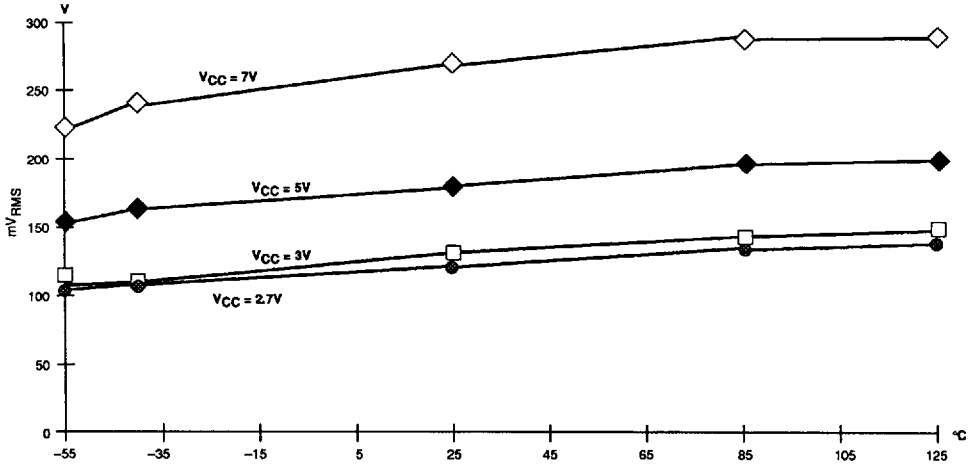
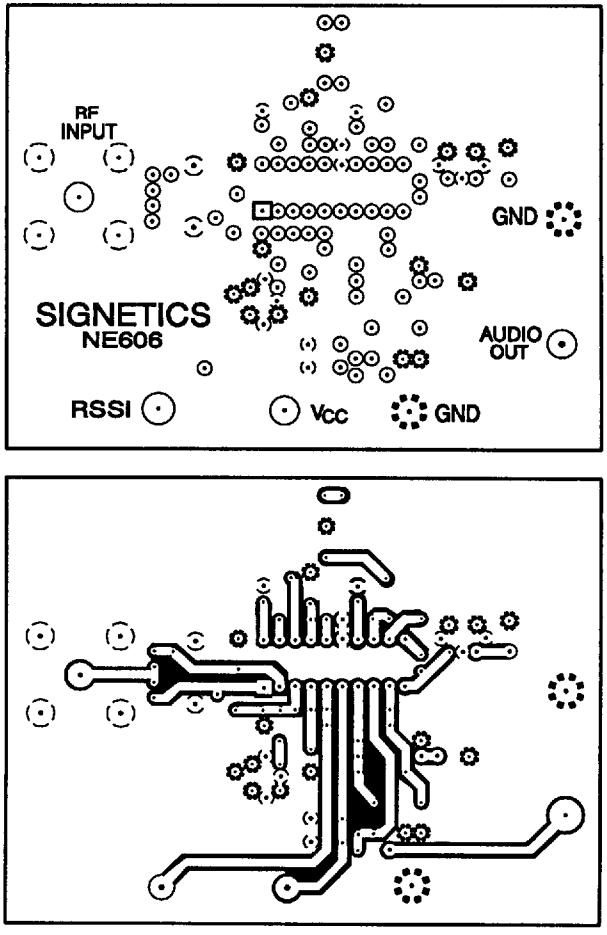


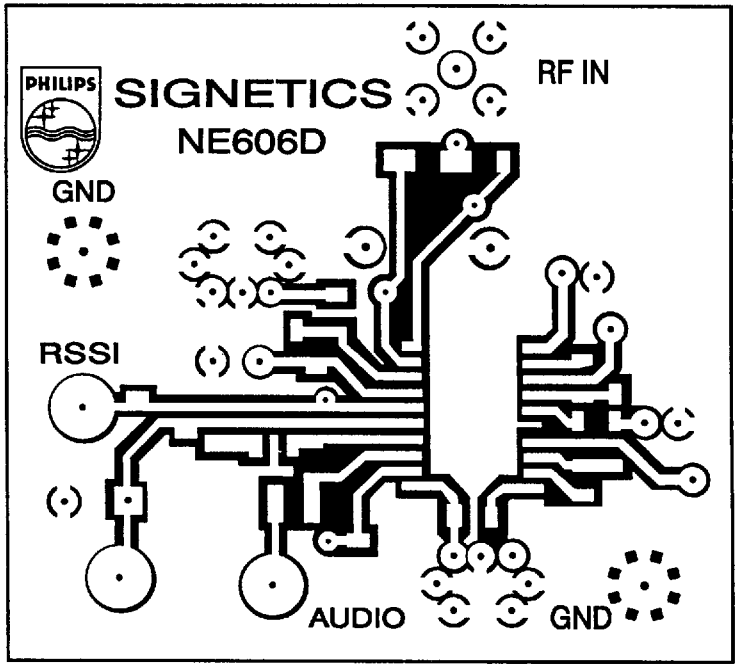

**Figure 15. Audio Output vs Temperature**




*Applies to Stand-Alone data sheets only.



**Figure 16. NE/SA606N DIP Product Board Layout (Actual Size* — For Reference Use Only)**




*Applies to Stand-Alone data sheets only.

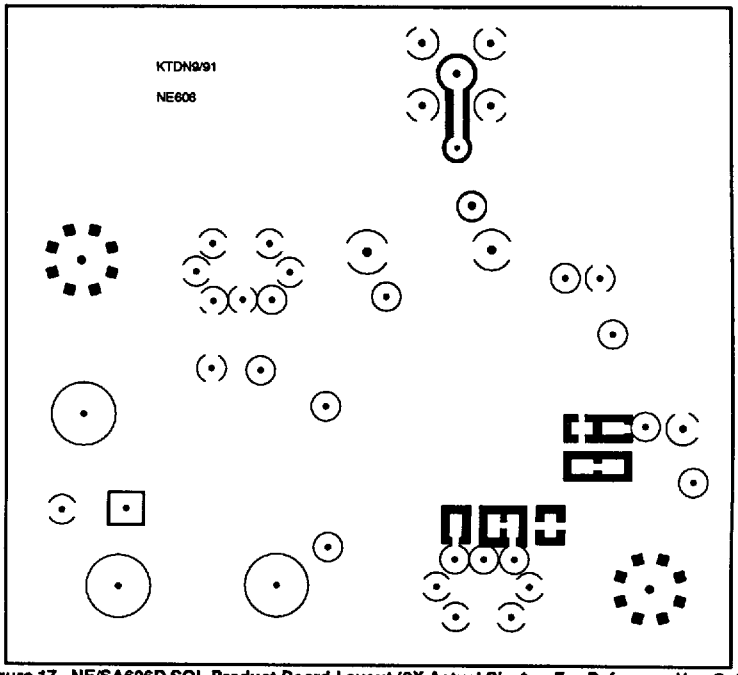



**Figure 17. NE/SA606D SOL Product Board Layout (2X Actual Size* — For Reference Use Only)**

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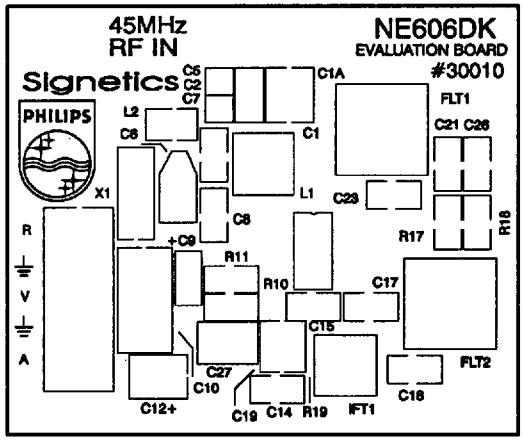
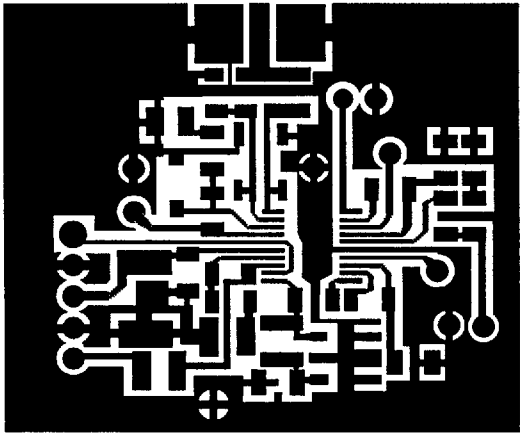
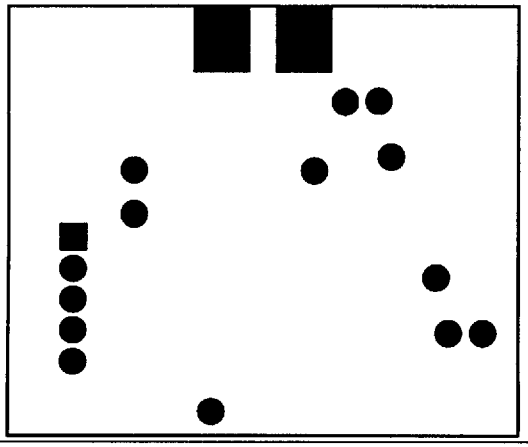
606 Silk Screen




606 TOP



606 BOTTOM



**NOTE;**
All views are TOP VIEW and not actual size. For reference only.