

## High performance low power mixer FM IF system

NE/SA615

## DESCRIPTION

The NE/SA615 is a high performance monolithic low-power FM IF system incorporating a mixer/oscillator, two limiting intermediate frequency amplifiers, quadrature detector, muting, logarithmic received signal strength indicator (RSSI), and voltage regulator. The NE/SA615 combines the functions of Signetics' NE602 and NE604A, but features a higher mixer input intercept point, higher IF bandwidth (25MHz) and temperature compensated RSSI and limiters permitting higher performance application. The NE/SA615 is available in 20-lead dual-in-line plastic, 20-lead SOL (surface-mounted miniature package) and 20-lead SSOP (shrink small outline package).

The NE/SA605 and NE/SA615 are functionally the same device types. The difference between the two devices lies in the guaranteed specifications. The NE/SA615 has a higher  $I_{CC}$ , lower input third order intercept point, lower conversion mixer gain, lower limiter gain, lower AM rejection, lower SINAD, higher THD, and higher RSSI error than the NE/SA605. Both the NE/SA605 and NE/SA615 devices will meet the EIA specifications for AMPS and TACS cellular radio applications.

For additional technical information please refer to application notes AN1994, 1995 and 1996, which include example application diagrams, a complete overview of the product, and artwork for reference.

## FEATURES

- Low power consumption: 5.7mA typical at 6V
- Mixer input to >500MHz
- Mixer conversion power gain of 13dB at 45MHz
- Mixer noise figure of 4.6dB at 45MHz
- XTAL oscillator effective to 150MHz (L.C. oscillator to 1GHz local oscillator can be injected)
- 102dB of IF Amp/Limiter gain
- 25MHz limiter small signal bandwidth
- Temperature compensated logarithmic Received Signal Strength Indicator (RSSI) with a dynamic range in excess of 90dB
- Two audio outputs – muted and unmuted
- Low external component count; suitable for crystal/ceramic/LC filters

## ORDERING INFORMATION

DESCRIPTION	TEMPERATURE RANGE	ORDER CODE	DWG #
20-Pin Plastic Dual In-Line Package (DIP)	0 to +70°C	NE615N	SOT146-1
20-Pin Plastic Dual In-Line Package (DIP)	-40 to +85°C	SA615N	SOT146-1
20-Pin Plastic Small Outline Large (SOL) package	0 to +70°C	NE615D	SOT108-1
20-Pin Plastic Small Outline Large (SOL) package	-40 to +85°C	SA615D	SOT108-1
20-Pin Plastic Shrink Small Outline Package (SSOP)	0 to +70°C	NE615DK	SOT266-1
20-Pin Plastic Shrink Small Outline Package (SSOP)	-40 to +85°C	SA615DK	SOT266-1

## PIN CONFIGURATION

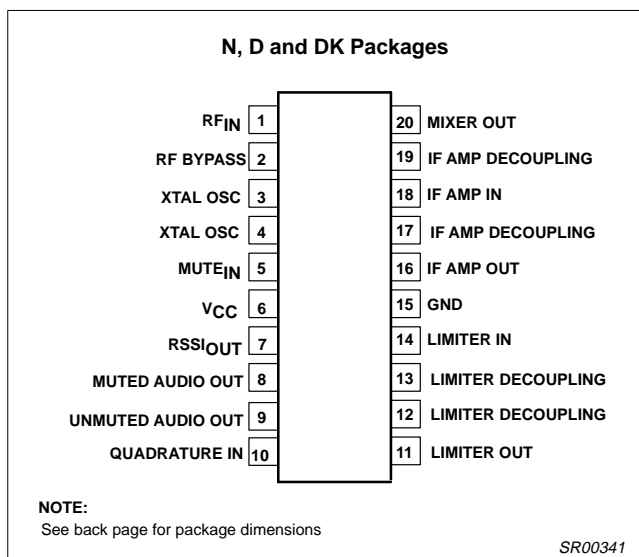


Figure 1. Pin Configuration

- Excellent sensitivity: 0.22 $\mu$ V into 50 $\Omega$  matching network for 12dB SINAD (Signal to Noise and Distortion ratio) for 1kHz tone with RF at 45MHz and IF at 455kHz
- SA615 meets cellular radio specifications
- ESD hardened

## APPLICATIONS

- Cellular radio FM IF
- High performance communications receivers
- Single conversion VHF/UHF receivers
- SCA receivers
- RF level meter
- Spectrum analyzer
- Instrumentation
- FSK and ASK data receivers
- Log amps
- Wideband low current amplification

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## BLOCK DIAGRAM

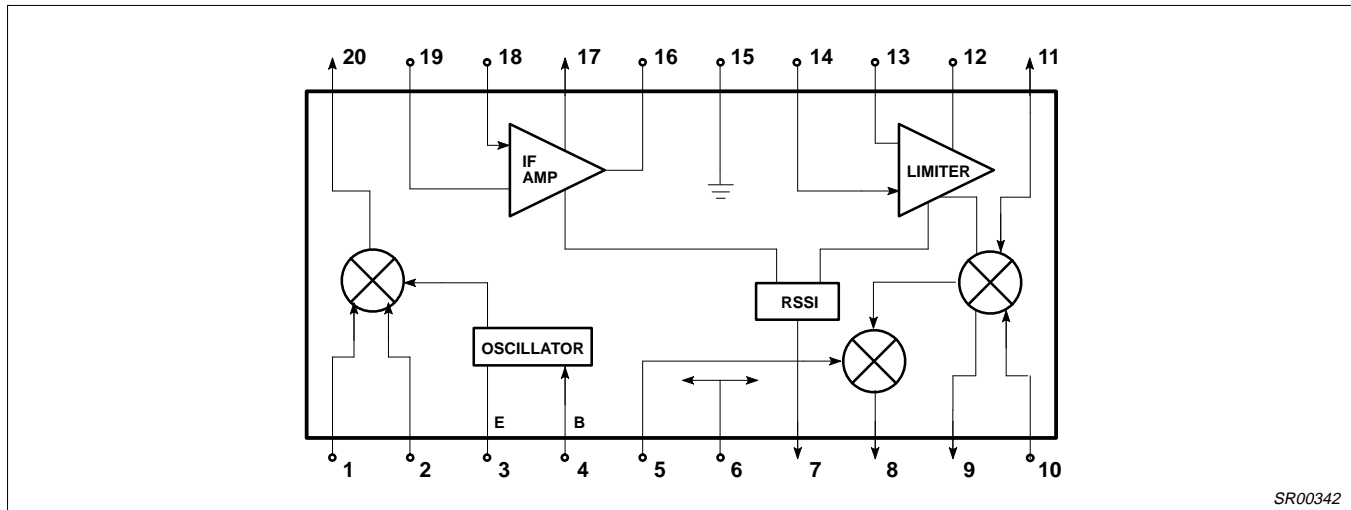


Figure 2. Block Diagram

## ABSOLUTE MAXIMUM RATINGS

SYMBOL	PARAMETER	RATING	UNITS
$V_{CC}$	Single supply voltage	9	V
$T_{STG}$	Storage temperature range	-65 to +150	°C
$T_A$	Operating ambient temperature range NE615	0 to +70	°C
	SA615	-40 to +85	°C
$\theta_{JA}$	Thermal impedance	D package	90
		N package	75
		SSOP package	117

## DC ELECTRICAL CHARACTERISTICS

$V_{CC} = +6V$ ,  $T_A = 25^\circ C$ ; unless otherwise stated.

SYMBOL	PARAMETER	TEST CONDITIONS	LIMITS			UNITS
			NE/SA615			
			MIN	TYP	MAX	
$V_{CC}$	Power supply voltage range		4.5		8.0	V
$I_{CC}$	DC current drain			5.7	7.4	mA
	Mute switch input threshold (ON)		1.7			V
	(OFF)				1.0	V

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## AC ELECTRICAL CHARACTERISTICS

$T_A = 25^\circ\text{C}$ ;  $V_{CC} = +6\text{V}$ , unless otherwise stated. RF frequency = 45MHz + 14.5dBV RF input step-up; IF frequency = 455kHz;  $R_{17} = 5.1\text{k}$ ; RF level = -45dBm; FM modulation = 1kHz with  $\pm 8\text{kHz}$  peak deviation. Audio output with C-message weighted filter and de-emphasis capacitor. Test circuit Figure 3. The parameters listed below are tested using automatic test equipment to assure consistent electrical characteristics. 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			UNITS
			NE/SA615			
			MIN	TYP	MAX	
<b>Mixer/Osc section (ext LO = 300mV)</b>						
$f_{IN}$	Input signal frequency			500		MHz
$f_{OSC}$	Crystal oscillator frequency			150		MHz
	Noise figure at 45MHz			5.0		dB
	Third-order input intercept point	$f_1 = 45.00$ ; $f_2 = 45.06\text{MHz}$		-12		dBm
	Conversion power gain	Matched 14.5dBV step-up 50 $\Omega$ source	8.0	13		dB
				-1.7		dB
	RF input resistance	Single-ended input	3.0	4.7		k $\Omega$
	RF input capacitance			3.5	4.0	pF
	Mixer output resistance	(Pin 20)	1.25	1.50		k $\Omega$
<b>IF section</b>						
	IF amp gain	50 $\Omega$ source		39.7		dB
	Limiter gain	50 $\Omega$ source		62.5		dB
	Input limiting -3dB, $R_{17} = 5.1\text{k}$	Test at Pin 18		-109		dBm
	AM rejection	80% AM 1kHz	25	33	43	dB
	Audio level, $R_{10} = 100\text{k}$	15nF de-emphasis	60	150	260	mV <sub>RM S</sub>
	Unmuted audio level, $R_{11} = 100\text{k}$	150pF de-emphasis		530		mV
	SINAD sensitivity	RF level -118dB		12		dB
THD	Total harmonic distortion		-30	-42		dB
S/N	Signal-to-noise ratio	No modulation for noise		68		dB
	IF RSSI output, $R_9 = 100\text{k}\Omega^1$	IF level = -118dBm	0	160	800	mV
		IF level = -68dBm	1.7	2.5	3.3	V
		IF level = -18dBm	3.6	4.8	5.8	V
	RSSI range	$R_9 = 100\text{k}\Omega$ Pin 16		80		dB
	RSSI accuracy	$R_9 = 100\text{k}\Omega$ Pin 16		$\pm 2$		dB
	IF input impedance		1.40	1.6		k $\Omega$
	IF output impedance		0.85	1.0		k $\Omega$
	Limiter input impedance		1.40	1.6		k $\Omega$
	Unmuted audio output resistance			58		k $\Omega$
	Muted audio output resistance			58		k $\Omega$
<b>RF/IF section (int LO)</b>						
	Unmuted audio level	4.5V = $V_{CC}$ , RF level = -27dBm		450		mV <sub>RM S</sub>
	System RSSI output	4.5V = $V_{CC}$ , RF level = -27dBm		4.3		V

## NOTE:

- The generator source impedance is 50 $\Omega$ , but the NE/SA605 input impedance at Pin 18 is 1500 $\Omega$ . As a result, IF level refers to the actual signal that enters the NE/SA605 input (Pin 8) which is about 21dB less than the "available power" at the generator.

## CIRCUIT DESCRIPTION

The NE/SA615 is an IF signal processing system suitable for second IF or single conversion systems with input frequency as high as 1GHz. The bandwidth of the IF amplifier is about 40MHz, with 39.7dB(v) of gain from a 50 $\Omega$  source. The bandwidth of the limiter is about 28MHz with about 62.5dB(v) of gain from a 50 $\Omega$  source.

However, the gain/bandwidth distribution is optimized for 455kHz, 1.5k $\Omega$  source applications. The overall system is well-suited to battery operation as well as high performance and high quality products of all types.

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The input stage is a Gilbert cell mixer with oscillator. Typical mixer characteristics include a noise figure of 5dB, conversion gain of 13dB, and input third-order intercept of  $-10\text{dBm}$ . The oscillator will operate in excess of 1GHz 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 of the mixer is internally loaded with a  $1.5\text{k}\Omega$  resistor permitting direct connection to a 455kHz ceramic filter. The input resistance of the limiting IF amplifiers is also  $1.5\text{k}\Omega$ . With most 455kHz ceramic filters and many crystal filters, no impedance matching network is necessary. 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 can be added between the first IF output (Pin 16) and the interstage network.

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  $90^\circ$  phase relationship to the internal signal, drives the other port of the multiplier cell.

Overall, the IF section has a gain of 90dB. For operation at intermediate frequencies greater than 455kHz, special care must be given to layout, termination, and interstage loss to avoid instability.

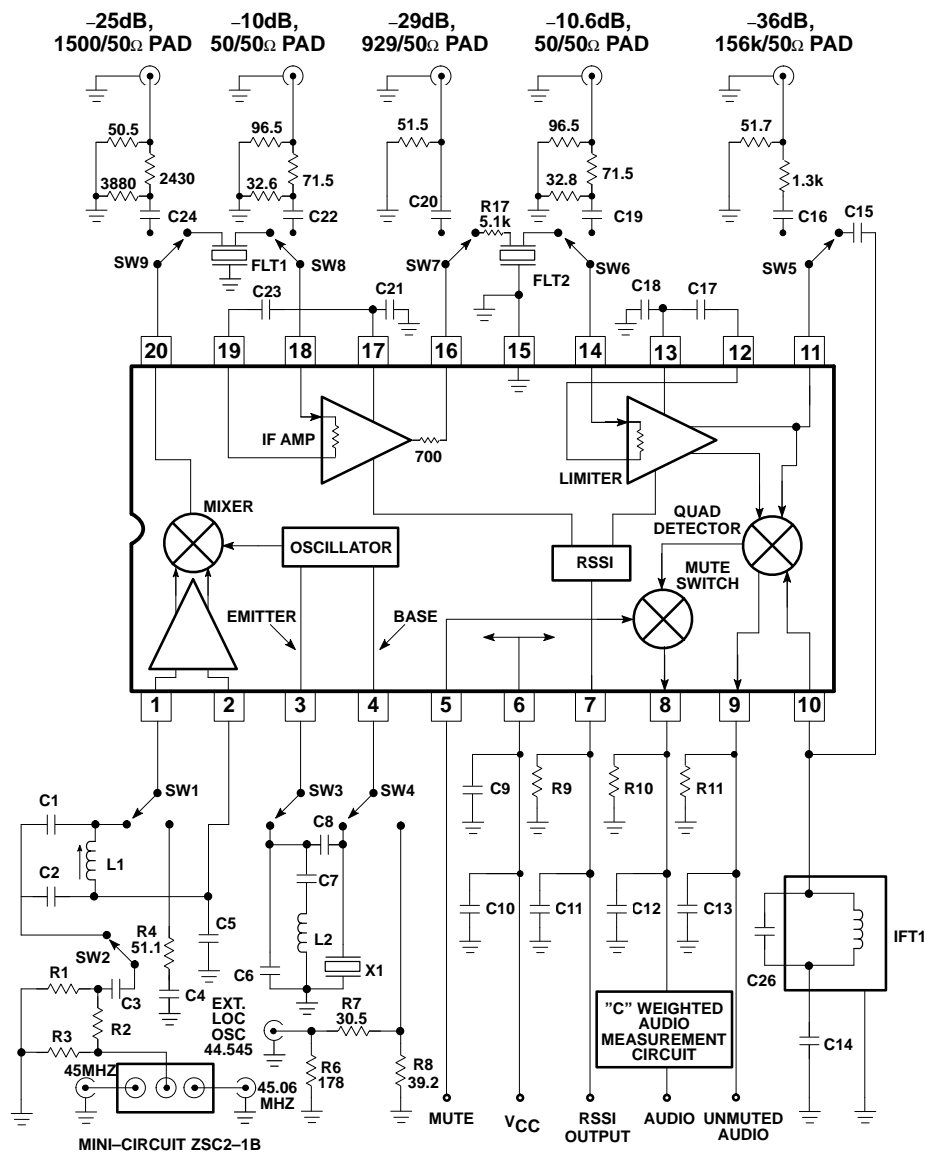
The demodulated output of the quadrature detector is available at two pins, one continuous and one with a mute switch. Signal attenuation with the mute activated is greater than 60dB. The mute input is very high impedance and is compatible with CMOS or TTL levels.

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.

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

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### Automatic Test Circuit Component List

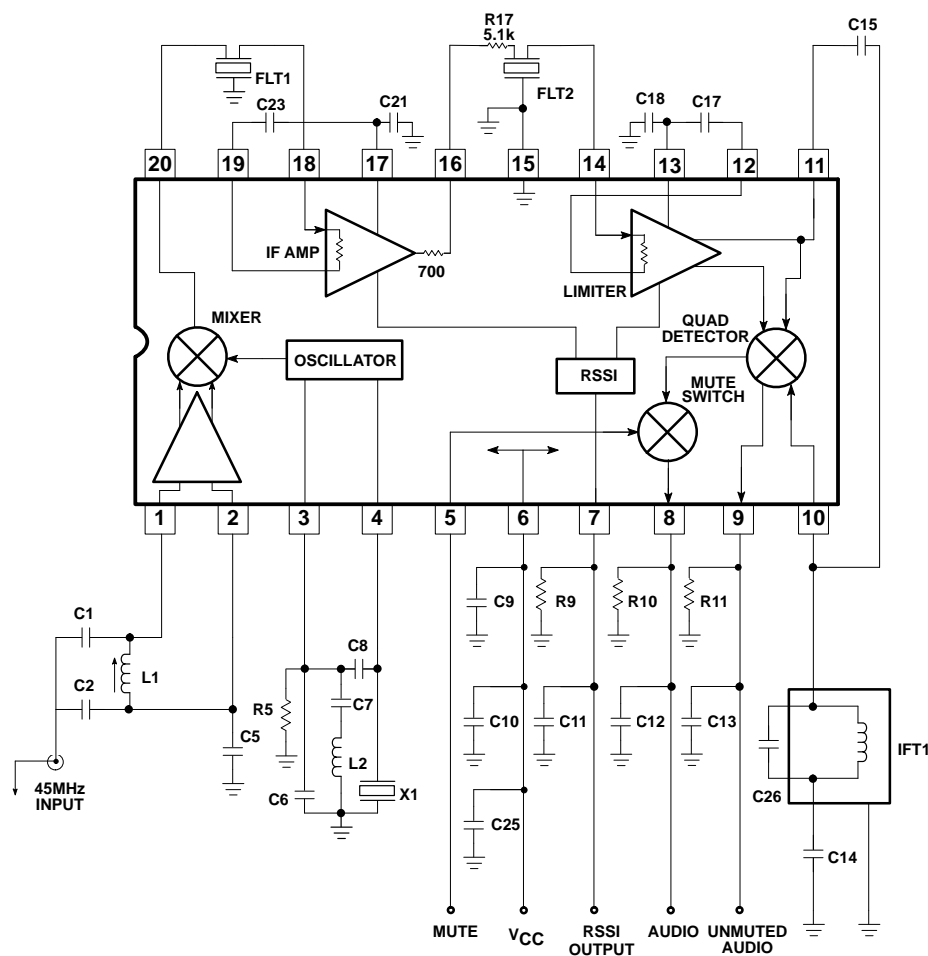
- |     |                                     |       |   |
|-----|-------------------------------------|-------|---|
| C1  | 47pF NPO Ceramic                    | C21   | 100nF $\pm 10\%$ Monolithic Ceramic       |
| C2  | 180pF NPO Ceramic                   | C23   | 100nF $\pm 10\%$ Monolithic Ceramic       |
| C5  | 100nF $\pm 10\%$ Monolithic Ceramic | C25   | 100nF $\pm 10\%$ Monolithic Ceramic       |
| C6  | 22pF NPO Ceramic                    | C26   | 390pF $\pm 10\%$ Monolithic Ceramic       |
| C7  | 1nF Ceramic                         | Flt 1 | Ceramic Filter Murata SFG455A3 or equiv   |
| C8  | 10.0pF NPO Ceramic                  | Flt 2 | Ceramic Filter Murata SFG455A3 or equiv   |
| C9  | 100nF $\pm 10\%$ Monolithic Ceramic | IFT 1 | 455kHz 270 $\mu$ H TOKO #303LN-1129       |
| C10 | 6.8 $\mu$ F Tantalum (minimum) *    | L1    | 300nH TOKO #5CB-1055Z                     |
| C11 | 100nF $\pm 10\%$ Monolithic Ceramic | L2    | 0.8 $\mu$ H TOKO 292CNS-T1038Z            |
| C12 | 15nF $\pm 10\%$ Ceramic             | X1    | 44.545MHz Crystal ICM4712701              |
| C13 | 150pF $\pm 2\%$ N1500 Ceramic       | R9    | 100k $\pm 1\%$ 1/4W Metal Film            |
| C14 | 100nF $\pm 10\%$ Monolithic Ceramic | R17   | 5.1k $\pm 5\%$ 1/4W Carbon Composition    |
| C15 | 10pF NPO Ceramic                    | R10   | 100k $\pm 1\%$ 1/4W Metal Film (optional) |
| C17 | 100nF $\pm 10\%$ Monolithic Ceramic | R11   | 100k $\pm 1\%$ 1/4W Metal Film (optional) |
| C18 | 100nF $\pm 10\%$ Monolithic Ceramic |       |   |

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

Figure 3. NE/SA615 45MHz Test Circuit (Relays as shown)

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### NE/SA615N Application Component List

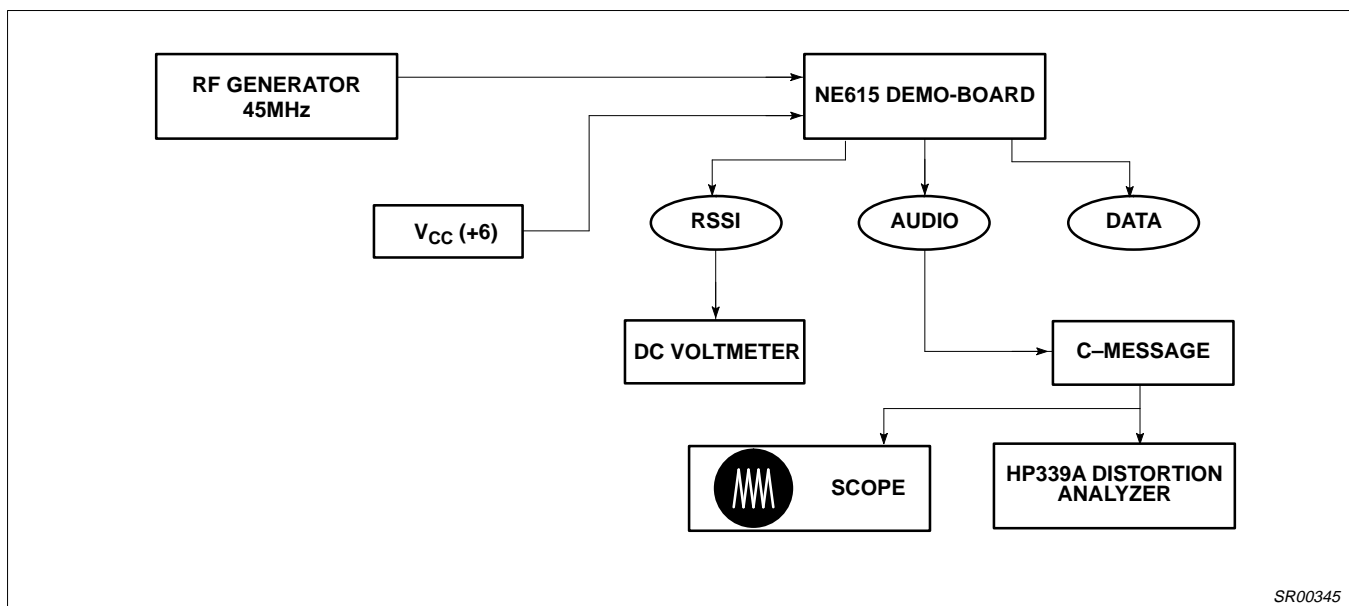
- |     |                                     |       |   |
|-----|-------------------------------------|-------|---|
| C1  | 47pF NPO Ceramic                    | C21   | 100nF $\pm 10\%$ Monolithic Ceramic       |
| C2  | 180pF NPO Ceramic                   | C23   | 100nF $\pm 10\%$ Monolithic Ceramic       |
| C5  | 100nF $\pm 10\%$ Monolithic Ceramic | C25   | 100nF $\pm 10\%$ Monolithic Ceramic       |
| C6  | 22pF NPO Ceramic                    | C26   | 390pF $\pm 10\%$ Monolithic Ceramic       |
| C7  | 1nF Ceramic                         | Flt 1 | Ceramic Filter Murata SFG455A3 or equiv   |
| C8  | 10.0pF NPO Ceramic                  | Flt 2 | Ceramic Filter Murata SFG455A3 or equiv   |
| C9  | 100nF $\pm 10\%$ Monolithic Ceramic | IFT 1 | 455kHz 270 $\mu$ H TOKO #303LN-1129       |
| C10 | 6.8 $\mu$ F Tantalum (minimum) *    | L1    | 300nH TOKO #5CB-1055Z                     |
| C11 | 100nF $\pm 10\%$ Monolithic Ceramic | L2    | 0.8 $\mu$ H TOKO 292CNS-T1038Z            |
| C12 | 15nF $\pm 10\%$ Ceramic             | X1    | 44.545MHz Crystal ICM4712701              |
| C13 | 150pF $\pm 2\%$ N1500 Ceramic       | R9    | 100k $\pm 1\%$ 1/4W Metal Film            |
| C14 | 100nF $\pm 10\%$ Monolithic Ceramic | R17   | 5.1k $\pm 5\%$ 1/4W Carbon Composition    |
| C15 | 10pF NPO Ceramic                    | R10   | 100k $\pm 1\%$ 1/4W Metal Film (optional) |
| C17 | 100nF $\pm 10\%$ Monolithic Ceramic | R11   | 100k $\pm 1\%$ 1/4W Metal Film (optional) |
| C18 | 100nF $\pm 10\%$ Monolithic Ceramic |       |   |

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

Figure 4. NE/SA615 45MHz Application Circuit

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SR00345

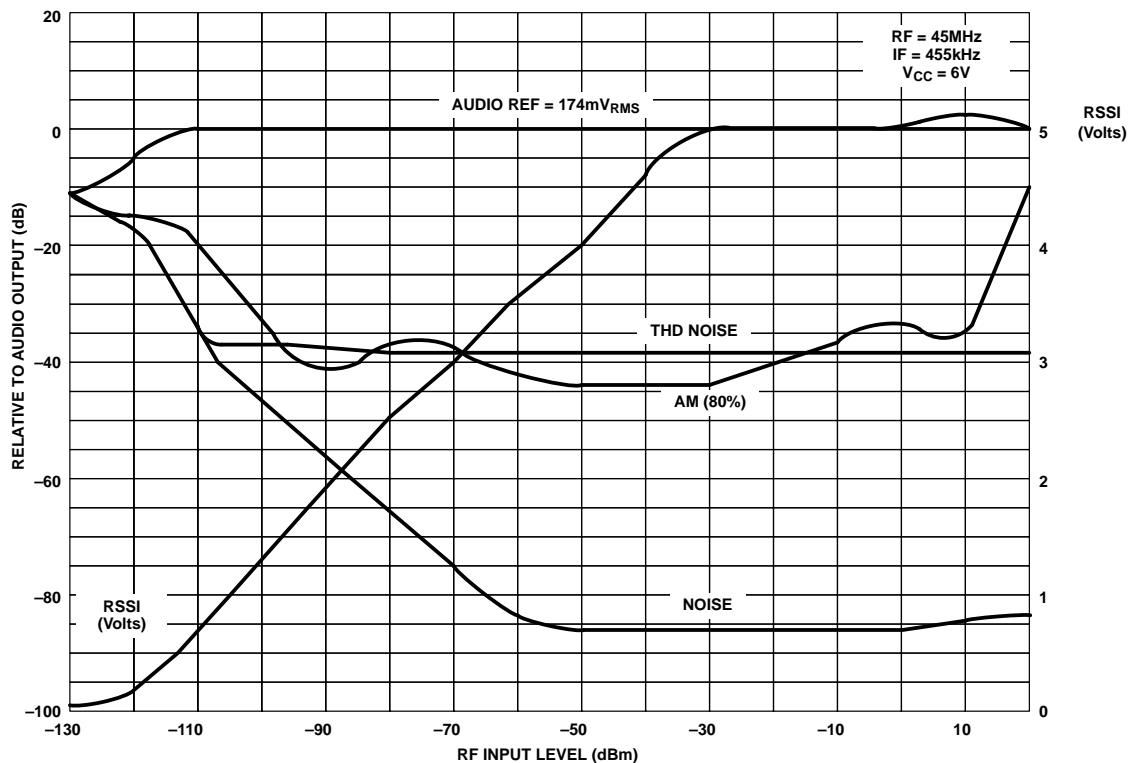
Figure 5. NE/SA615 Application Circuit Test Set Up

**NOTES:**

1. C-message: The C-message filter has a peak gain of 100 for accurate measurements. Without the gain, the measurements may be affected by the noise of the scope and HP339 analyzer.
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 0.22 $\mu$ V or -120dBm 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 250mV 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 10–15 $\mu$ F 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 0.1 $\mu$ F 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 22k $\Omega$ , but should not be below 10k $\Omega$ .

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SR00346

Figure 6. NE615 Application Board at 25°C