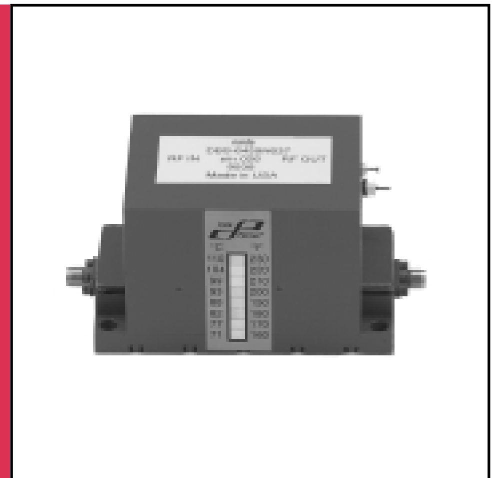
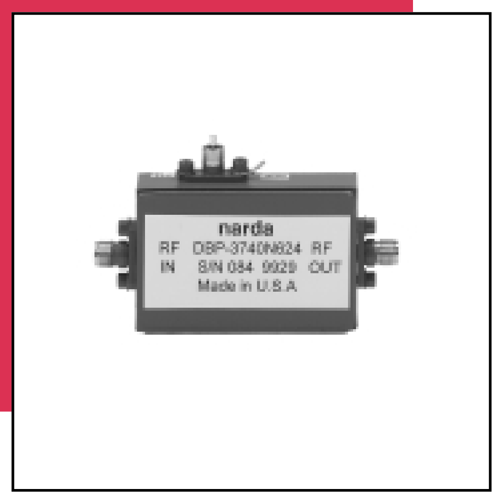
GaAs Amplifiers





Narda GaAs Amplifiers

Narda offers a variety of GaAs amplifiers in frequency bands from 0.5 GHz to 65 GHz.

We have amplifier designs to accommodate all markets and they can be characterized as follows:

Military Amplifiers and Microwave Assemblies

These amplifiers are designed to withstand a rugged military environment. All amplifiers are laser-weld hermetically sealed. They incorporate a highly reliable thin film technology with aluminum, low-profile and low-weight mechanical housing. Narda offers a variety of gain amplifiers, LNAs, power amplifiers, and active multipliers.

Narda specializes in amplifiers and microwave assemblies (MICs) with added functions such as couplers, detectors, mixers, filters, switches, linearizers, isolators and TTL. These amplifiers and MIC assemblies are designed to specific customer documentation and manufactured under a disciplined program management.

Narda offers over 1000 catalog standard types of amplifiers for narrow and wide band applications. However, with our extensive gain and power modules library, we can tailor an amplifier or MIC to your custom requirement at affordable cost.

TE Band Amplifiers

These amplifiers are designed for test equipment with wide frequency band applications such as 0.5-18 GHz, 18-26.5 GHz, 26.5-40 GHz, 18-40 GHz, 33-50 GHz, and 40-60 GHz. Narda also offers a variety of active multipliers, gain amplifiers, LNAs and power amplifiers in these bands.

Communications Band Amplifiers

Designed to accommodate a specific narrow band for uplink or crosslink applications, Narda offers gain amplifiers from 10 to 60 dB gain, LNAs and power amplifiers to 5 Watts and 10 Watts.

Base Station and Repeater Amplifiers

These amplifiers are designed to accommodate a specific narrow band for short haul or long haul applications. Narda offers gain amplifiers from 10 to 90 dB gain, LNAs and power amplifiers to 5 Watts and 10 Watts.

These amplifiers are designed with a most reliable thin film technology that features the same design for military and space applications.

PTP and PTMP Amplifiers

These amplifiers are designed to accommodate the Point-to-Point (PTP) and Point-To-Multi-Point (PTMP) radios at 20, 23, 26, 28, 31, 38, 42, 50, 60, and 65 GHz. Narda offers a variety of gain amplifiers, LNAs and power amplifiers. These amplifiers are designed to accommodate a linear modulation requirement such as QPSK and QAM (16 to 512).

However, Narda also offers very low cost **transceivers** for the PTMP and LMDS market that utilize MMIC insertion on softboard with pick-and-place and ATE manufacturing process. These **transceivers** are highly reliable at a very low cost and a very high delivery rate from 100 PCs to 5000 PCs per month.

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Care and Handling of Amplifiers

Power Supply

DC Power Supply Voltage

The specified input voltage is the minimum value required for proper operation. Contact Narda for operation above the minimum value to prevent possible shutdown due to internal thermal safeguards.

Reverse polarity protection, over voltage protection, and dual bias voltage sequencing (when required) are incorporated into the design of all products to prevent accidental damage by the application of incorrect DC supply voltage.

The guaranteed amplifier performance depends on operation at the specified DC supply voltage and where constant performance is a requirement, the supply voltage should be kept constant and well regulated.

RF Input Power

Input Power Withstanding Capability of Transistor Amplifiers

Each GaAs FET or bipolar transistor has its own unique ability to withstand excessive input power levels. This capability is related to device geometry, metal thickness, fabrication techniques and materials. Since the input circuit of most transistor amplifiers is tuned for maximum power transfer, the power withstanding capacity of an amplifier is practically the same as that of the input transistor or transistors.

If excessive power is applied to a transistor amplifier, the first measurable effect is almost always an increase in noise figure. A somewhat higher power will further degrade noise figure and decrease the gain of the amplifier. If the input power level is even higher, the input transistor will ultimately fail.

Such failures are most often seen in radar applications. In most radar systems, the receiver and high power transmitter are always connected to the same antenna and isolated with a passive diplexer. The high power signal that appears at the receiver port during transmit periods is reflected to a large extent by a TR (transmit-receive) switch which uses a gas tube, solid state device or a combination of both. Since these switches are not perfect, some transmitter power invariably appears at the receiver input usually in the form of a high power spike and a lower power flat leakage.

In discussing the ability of an amplifier to survive high power levels, the input signal is generally described using the following terms.

Peak Pulse Power

The instantaneous maximum power occurring during carrier-frequency cycle. Expressed as “X” power for “Y” time.

Rise Time

The interval between the instants at which the instantaneous power first reaches 10% and 90% of the peak pulse power on the leading edge of the pulse.

Fall Time

The interval between the instants at which the instantaneous power first reaches 90% and 10% of the peak pulse power on the trailing edge of the pulse.

Pulse Width

The time interval between the points on the leading and trailing edges of the pulse at which the instantaneous power is 3 dB less than the maximum instantaneous power of the pulse (half-power points).

Pulse Duty Cycle

The numerical ratio or percentage of the average pulse duration to the average pulse spacing. This is equivalent to the product of the average pulse duration and the pulse repetition rate.

Pulse Repetition Rate

The number of pulses occurring per unit time.

To examine the relationship between these factors and the resulting energy, power and voltage appearing at an amplifier input, we can examine the following example taken from a typical radar system. Assume that the leakage signal from the TR switch consists of a 10 ns, +50 dBm (100 W) spike followed by a 50 μs, + 30 dBm (1 W) flat. The duty cycle is 2.5% (.025).

RF Input Power Levels

Narda guarantees the amplifiers to be unconditionally stable under any input/output condition. However, for extended operating life it is recommended that the output be loaded during operation. This load is especially important when operating with high input drive levels.

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The maximum safe RF input power level which may be applied to an amplifier is +20 dBm CW. Pulsed input power level may be applied up to +30 dBm PROVIDED the pulse width and duty cycle average +20 dBm or less over one cycle. Higher levels can be obtained with internal input limiters on most models. Please contact Narda Amplifier Sales for input levels exceeding these limits.

Input Limiters for Amplifier Protection

Currently Narda can equip most solid state amplifiers in this catalog with internal or external input limiters that will provide protection from +50 dBm peak (up to 5s duration with low duty cycle) and up to +30 dBm continuous input power.

Narda uses a number of basic PIN diode limiters for input protection. They range from simple single-diode self-biased circuits through multi-diode cascades.

To discuss your requirements for Narda low noise amplifiers combined with input limiter protection contact your representative.

Thermal Considerations

Thermal Considerations - Power Amplifiers

With the increasing usage of high power microwave devices, a definite factor in the performance of GaAs FETs and MMICs is imposed by the actual channel temperature of the device. The lifetime or MTBF of a GaAs FET varies inversely with its channel temperature. Narda design engineers make every effort to assure that the design of the amplifier does not allow the FET's operating channel to exceed the specified maximum rating. GaAs Power FETs and MMICs built with Narda designs and fabrication technology offer the potential for useful lifetimes exceeding those of the systems in which they are used.

It is recommended that precaution be taken to protect the amplifier from the following conditions:

- Excessive RF input signals (see applications note "RF Input Power Levels)
- High-voltage power supply spikes (see applications note "DC Power Supply Voltage")
- Improper heat sinking (see applications note "Heat Sinking")

Narda guarantees the amplifiers to be unconditionally stable under any input/output condition. For prolonged operating life, it is recommended that the output always be loaded during operation, especially when operating with high input drive levels.

All Narda Power Amplifiers are designed to be cooled by conduction through the amplifier base plate to the external heat sink and/or mounting surface. Application of DC power without proper heat sinking may result in degraded performance and/or permanent damage to the amplifier. It is ultimately the system designer's responsibility to assure that adequate heat sinking is provided to maintain the amplifier baseplate temperature within the guaranteed temperature specification.

Proper heat sinking is dependent upon a number of system design factors (i.e. configurations/ size constraints, air flow, ambient temperatures, power dissipation, thermal resistance, etc.) Power dissipation (in watts) may be determined by multiplying the applied DC voltage by the operating DC current. Thermal Resistance, like electrical resistance, is a measure of the ability of a device or interface to enhance or impede the flow of heat. It is a function of heat sink design, surface area, convection coefficient, power dissipation, and generally is expressed in °C/watt. The only way thermal resistance can be reduced is either by increasing the physical size of the heat sink (i.e. changing surface area) or by moving more air across the sink (i.e., changing from natural convection to forced convection coefficients).

Due to these variables and without calculating for each specific application, the following recommendations are offered as a guide to proper heat sinking which will enhance the useful lifetime of the amplifier.

- Temperature should be monitored by means of thermocouple connected to a temperature measuring device and attached as close as possible to the amplifier base plate on the mounting surface.
- A thermal compound should be applied between the amplifier base plate and the heat sinking surface. These compounds reduce the high thermal impedance of the air gap between the case and the sink.
- Consider specific system variables when calculating power dissipation and thermal resistance to determine the size and heat dissipating characteristics of the heat sink material.
- When possible, forced air cooling should be utilized to reduce the operating temperature of the amplifier.
- When space is available, finned cooling plates should be employed to further enhance convective and forced air cooling.

Bandwidth Limitation With External Filtering

The guaranteed frequency range of all Narda amplifiers represents the range in which all guaranteed performance parameters are met and not the 3 dB down points

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on the amplifier gain curve. There is no way to determine the 3 dB points from the basic amplifier specifications and the amplifier may continue to exhibit large amounts of gain over a considerably wider frequency range. If response to out-of-band signals is a problem in a system design, it may be necessary to provide external filtering to limit the overall system bandwidth to a known range.

Safety

Narda does not use hazardous or toxic material in the final assembly of our amplifiers. In the majority of the amplifiers shown in this catalog, reasonable product safety features (over-voltage and reverse polarity protection) are a part of the final assembly. TESTING, SCREENING and TEST DATA

Certified Test Data

Certified test data is provided with each Narda amplifier. Data is taken with equipment calibrated and maintained in accordance with MIL-C-45662.

All amplifiers are routinely tested for:

- Small Signal Gain
- Noise Figure
- Power Output at the 1 dB gain compression point or saturation Output Power
- Input VSWR
- Output VSWR

Test Data is supplied with each unit for performance at +25°C. Specifications are guaranteed over the stated temperature ranges and are tested to ensure compliance.

All parameters indicated in the Narda Amplifier Data Book as “minimum” or “maximum” are tested as an integral part of the production process. All specifications indicated as “typical” are sample tested on a regular basis and serve as an indication of the performance of the units. For specific information on test set-ups used to measure the performance of Narda amplifiers and equipment recommendations, please contact Narda Amplifier Sales.

Amplifier Parameters and Performance

Gain

The ratio between the output power and the input power of the amplifier (in dB) is a measure of the gain or amplification available from the amplifier. Small signal gain (normally called “gain”) is specified as operating in the Small Signal or Linear Gain region and measured with a source and load impedance of 50 ohms. The Small Signal Gain is normally measured a minimum of 10 dB below the 1 dB Gain Compression Point.

Gain Flatness

The Small Signal Gain Flatness is expressed within the frequency range specified as the amplifier bandpass and at a fixed baseplate temperature as ± some limit (in dB) from the nominal gain level. For example, an amplifier with a small signal gain flatness specification of 1.0 dB would have a maximum of 2.0 dB peak-to-peak gain variation.

Small Signal Gain and Gain Variation Vs. Temperature

The gain of a GaAs FET amplifier exhibits an inherent and almost linear tendency to change with temperature. The actual gain variation of an amplifier depends on a number of design factors and a good rule of thumb is that gain will vary by 0.015 dB/oC per GaAs FET stage. For example, without temperature compensation, the gain of a 6 stage amplifier will decrease by approximately 6.3 dB at +95°C and increase approximately 7.2 dB at -55°C.

Temperature Compensation

Where stable gain performance is required over a wide operating temperature range (e.g. -55 to +100°C), compensation of the gain variation with temperature is required.

Compensation is achieved by a variable gain element. Gain variation over temperature can be controlled by factor of 5 to 10 times using compensation, depending on temperature range, gain, and operating bandwidth.

Gain Variation vs. Temperature in Transistor Microwave Amplifiers

The gain of both GaAs FET and bipolar transistors exhibits a change with changes in the device temperature. Although the actual gain variation in a practical amplifier stage depends on a number of design factors, a rule of thumb states that a GaAs FET stage will vary at a rate of approximately .015dB/°C. Thus a ten-stage GaAs FET amplifier with a nominal gain of 45 dB at 25°C will exhibit a gain of approximately 30 dB at +125°C and 60 dB at -75°C if no temperature compensation is used. Bipolar transistor stages have a nonlinear gain vs. temperature characteristic, with maximum gain occurring at approximately 0°C.

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Relative Gain vs. Temperature

Gain variation with temperature can be minimized using several different design techniques. Three gain compensation methods used at Narda are:

1. Temperature Variable Attenuator. If an attenuator incorporating temperature-dependent elements is carefully designed and optimized, and inserted in an amplifier cascade, it can be made to change in attenuation inversely with the temperature-induced gain changes of the amplification stages. This form of temperature compensation is particularly applicable to GaAs FET amplifiers because of the linear gain vs. temperature characteristic of GaAs FET devices.

In Narda temperature-compensated GaAs FET amplifiers, the temperature-variable attenuator is synthesized by driving a voltage-variable attenuator with a bias voltage derived from a temperature detection circuit. This allows the complete amplifier with temperature compensation to be fine tuned to maintain the overall gain within a narrow "window" over a wide temperature range.

2. Bias compensation: A thermistor, diode junction or other temperature-variable element is incorporated in the bias network of the amplifier stage. The bias system is adjusted so that the current through the device tends to increase with temperature, thus tending to increase the gain while the inherent gain of the active device is tending to decrease. This technique can be quite effective over a useful temperature range.

3. Heater Blanket Temperature Control: If the temperature of the transistor is not permitted to vary, the gain will remain constant regardless of changes in outside ambient temperature. In the heater blanket technique, the amplifier is thermally insulated and maintained at its maximum operating temperature using a proportionally-controlled heater. This is the most effective form of temperature compensation currently available, and is also the most expensive. It is used in a number of specially designed amplifiers for critical applications.

NOISE FIGURE

All components in a given system generate their own internal noise ("white noise"). The comparison of this "white noise" to the noise level desired is the signal-to-noise ratio. This is measured in dB. Noise Figure is the measure of the signal-to-noise reduction by the component.

An Automatic Noise Figure Meter is the most common method of measurement. A test set-up including a mixer and IF preamplifier can make measurements beyond the capability of the noise figure meter alone. The solid-state noise source can operate to 18 GHz and have a noise ratio of approximately 15 dB. Versatile and accurate measurement is achieved when the noise figure meter is "zeroed" and then properly driven (a system gain high enough). Some of the measurement errors can be mismatch (random phase), noise source variations (0.2dB), and the accuracy of the noise meter itself (normally 0.1 dB over most of their range).

Precautions should be taken, if a gas tube noise source is used, to assure that large voltage "spikes" will not be applied to the amplifier input. This can result in damage or erroneous Noise Figure results. Narda recommends the use of diode noise source such as the HP 346B.

Amplifier Dynamic Range

Once the intercept point of an amplifier is known, the spurious-free dynamic range can be calculated from the equation:

Spurious Free Dynamic Range (dB) = 2/3 (P1-P-10 Log BW-NF)

Where

P1 = Input intercept Point (obtained by subtracting the amplifier gain from the output intercept point given on data sheets).

P= effective input noise power with no signal = -114 dBm/MHz

BW= System noise bandwidth in MHz (controlled by any filtering or other selectivity in the system., or by the amplifier bandwidth if no selectivity is provided).

NF= Amplifier Noise Figure in dB.

Harmonic Distortion

Harmonic distortion results from non-linear amplifier gain and appears as output signals at integral multiples of the input signal frequency. Since harmonic distortion is a function of input power, it is usually specified in terms of the relative level of the harmonics with respect to the power of the fundamental signal.

The actual broadband characteristic of the amplifier (which may be wider than the required passband specified) may present significant gain at harmonic frequencies and thereby increase the harmonic output problem.

Second harmonic content is related to the device distortion and the frequency response of the circuit utilized to build the amplifier. The hybrid coupler input network and output network are the major components in determining passband response. Second harmonics occurring within the passband of the amplifier will typically be 15 to 18 dBc at the amplifier's specified 1 dB Gain Compression Point. Third harmonics are typically an additional 5 to 7 dB below

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this level. As the circuit's passband narrows, the resulting second and third harmonics attenuate rapidly.

AM-PM Conversion

As the input signal level applied to a transistor amplifier is increased until some degree of gain compression is produced, further increases in signal amplitude will result in a slight shift of the amplifier phase delay. This phenomenon is known as AM-PM conversion and can be thought of as a result of the change of the transistor operating parameters from the small-signal to large-signal conditions. Many Narda amplifiers include a guaranteed specification that AM-PM conversion will not exceed a certain value, on the order of a few tenths of a degree per dB increase in power output at a nominal power output level. If the input signal is further increased, the amount of AM-PM conversion will continue to increase reaching a maximum value when one of the amplifier stages is driven into full saturation. The maximum value will normally never exceed a few degrees/dB near amplifier saturation, and may generally be ignored.

Any limiters in a system are usually the major contributors to overall AM-PM conversion. Perhaps the worst case example is when a transistor amplifier is used in a receiving system in close proximity to a nearby transmitting system operating on a different frequency and the leakage power is sufficient to drive the limiters into their operating region. The result will usually be a noticeable slope in the baseband frequency response which will take place only when the transmitter is operating.

Matching

The Matching Specification over the specified passband is the capability of a given set of amplifiers to equal each other with respect to the matching parameter (gain, output power, etc.). Matching implies there is not a means to compensate for different levels between the amplifiers in a given set.