

RF LINEAR HYBRID AMPLIFIERS

Two sources of a new family of medium power broadband gain blocks for RF applications.

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A new class of low cost, high performance hybrid amplifiers has emerged to assist the design engineer working in the frequency range of 1 to 500 MHz. Utilizing the low distortion and wide dynamic range performance technology developed for the CATV industry, these amplifiers feature power output capabilities previously unavailable in hybrid circuits.

What Are They?

RF linear hybrid amplifiers represent a new family of medium power, broadband gain blocks for multi purpose RF applications. Internally matched at both the input and the output for either 50 ohm or 75 ohm systems, these devices cover gains ranging from 17 to 35 dB, and can accommodate output power levels in excess of 400 mW. Linear class A bias conditions accommodate third order intercept values in excess of + 45 dBmV. Depending on quantity and model selected, most prices fall in the range of \$30. to \$60. If you've been using transistors like the 2N3866, 2N5109, or stud mounted devices, read on. You may save a lot more than just design time.

Construction

RF linear hybrid amplifiers utilize the thin film manufacturing and construction techniques developed for the demanding CATV industry. All ceramic substrates are alumina (A1203) with gold conducting paths. Resistors are either cermet or nichrome, and are laser trimmed to better than one percent tolerance. For maximum MTBF, gold metallized transistor die are used incorporating resistive ballasting in the emitter fingers to provide even thermal distribution across the surface incorporating resistive ballasting in the emitter fingers to provide even thermal distribution across the surface of the die and to eliminate "hot spotting." These transistor die are subjected to rigorous testing through an extensive wafer qualification program before being mounted on the circuit. The hybrid manufacturer must insure that the transistors used will meet the exacting requirements for gain, distortion, and noise figure.

Basic Circuit

To meet the stringent performance requirements of low distortion and low noise figure, the basic parallel cascade

circuit shown in Figure 1 has emerged as the standard gain block used in CATV repeater amplifiers. Using resistive feedback techniques to assure product uniformity, this basic circuit accomplishes gain functions ranging from 17 to 25 dB. For higher gain models, two sections of this circuit are cascaded as shown in Figure 2. To accommodate the increased package density in the same form factor, the transmission line transformers are mounted on a bridge assembly suspended above the substrate.

Packaging Technique

The form factor standardized by the CATV industry allows the hybrid amplifier to be bolted directly to the chassis frame for maximum power dissipation. The pins are located on 0.100" centers for easy connection to a printed circuit board. Mating sockets are manufactured Amphenol (P/N 502-20071-572) and Barnes (P/N 027-018-02).

One note of caution. DO NOT attempt to lap or file the heatsink of the hybrid amplifier. Not only does this void the warranty (considered "mishandling" by the manufacturer), but you can induce substrate cracking during the machining operation.

Heatsink Your Hybrid

Like all RF power devices, hybrid amplifiers require heatsinking for proper operation. How much heatsinking is necessary? As much as is required to maintain the case operating temperature at the maximum value under worst case ambient temperature and maximum supply voltage. The presence or absence of the RF signal is insignificant due to the class A bias conditions. Reducing the supply voltage will decrease the power consumption, but it will also decrease the linearity. Attach the hybrid amplifier directly to the chassis, to a module card sidewall, to a small baseplate, or to a mounting bracket that is connected to one of the above. But before you complete your design, verify that the maximum case (flange) temperature for the hybrid amplifier is within the manufacturer's specified limits under your worst case operating conditions. This will insure that the maximum junction temperatures of the individual transistor die will not be exceeded (usually 140°C).



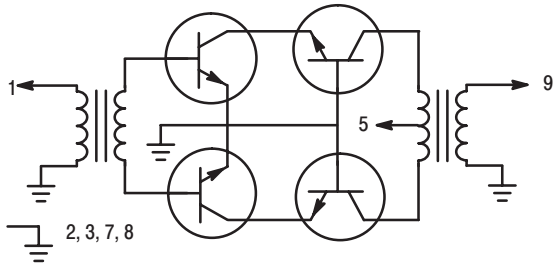


Figure 1. Single Parallel/Cascade Circuit

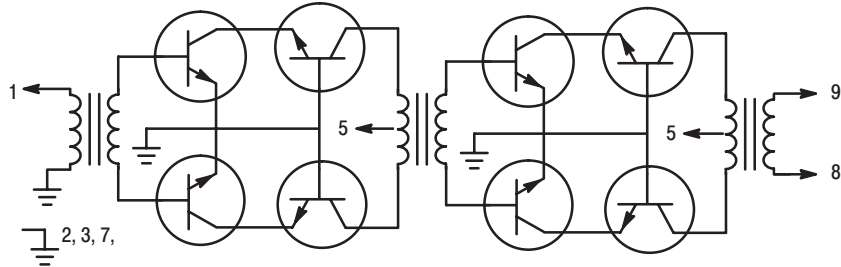


Figure 2. Double Parallel/Cascade Circuit

Electrical Performance Features

Gain — RF linear hybrid amplifiers are fixed gain devices (17 to 35 dB) which are fully cascadable for additional gain. If adjustable gain (AGC) is required for a particular application, it must be added externally (as with a conventional pin diode attenuator).

Frequency Range — These hybrid amplifiers utilize broadband transmission line transformers and 5 GHz fT transistor die to achieve wide bandwidths and linear phase response. Although some models may be optimized over a particular frequency range to fit a certain market, these hybrid amplifiers will often deliver satisfactory performance beyond the frequency ranges specified by the manufacturer.

Impedance — All hybrids are internally matched at both the input and the output for either 50 or 75 ohms. This not only reduces the external components normally required to match to these impedances in discrete designs, but it also simplifies the requirements for interfacing printed circuit board connections. For short path lengths, strip line width has little effect on RF performance.

Output Power — RF linear hybrids are often operated at power levels well below their maximum output capability (for example, in receiver applications). In such cases, operation at a reduced power supply voltage is recommended to reduce power consumption (assuming the full dynamic range is not required).

The maximum power capability for linear class A operation of these circuits may be restricted by several factors:

- a) The operating supply voltage, which limits the maximum AC peak to peak swing.
- b) The quiescent bias conditions, which limit the maximum current swing across the transformed load impedance.

- c) Core saturation in the output transformer, a condition aggravated by high permeability ferrites operating at high ambient temperatures.

Changes in Performance with Supply Voltage — Simply as a point of reference, most RF linear hybrid amplifiers are characterized at a supply voltage of 24V. However, a design engineer may operate above (to increase available output power) or below (to reduce DC power consumption) the rated supply voltage and observe little or no change in gain or frequency response. However, certain specifications are directly affected by the supply voltage:

- a) Current consumption. These hybrid amplifiers are biased (quiescent operating point) in a linear mode for class A operation. The higher the supply voltage, the more current they draw. The lower the supply voltage, the lower the current consumption. There is a 1:1 linear relationship between supply voltage and current consumption. Therefore, power consumption varies as the square of the supply voltage.
- b) Output power capability. As the supply voltage increases, so does the maximum available output power (higher peak to peak AC swing is possible across a given load).
- c) Linearity. Third order intercept, a measure of linearity, is directly related to supply voltage. In many applications, however, these RF hybrid amplifiers offer more linearity than required. In these cases operation at a lower supply voltage is recommended to reduce power consumption.
- d) Noise Figure. Just like a low noise transistor, the lower the bias current (or supply voltage, for these hybrid amplifiers), the lower the noise figure.

Reliability Screening, Military Applications

Since reliability is a major factor in the profitability of CATV systems, the component manufacturers who are supplying hybrid circuits in volume to this competitive industry have developed extensive data bases to insure the reliability of their product. Additional reliability screens uncommon to commercial products are often added at the manufacturer's expense to insure against field failures. Reliability is a major consideration, but these hybrid devices were not designed to qualify to MIL-STD-883, level B.

For example, the caps are sealed with epoxy

(nonhermetic). The physical mass of the ferrite transmission line transformers prohibits excessive levels of mechanical shock and variable frequency vibration. However the manufacturers should be consulted for specific applications, because hybrid amplifiers of this generic type have qualified for certain military programs.

Why Use a Hybrid Circuit?

Many engineers can design a circuit with discrete components to do exactly what they want. Selecting a hybrid amplifier from a standard product line results in some compromise, but usually offers several advantages:

Who Uses Them?

Because of their wide bandwidth and linear operation, RF linear hybrids are effective for digital (or pulse) applications as well as for analog waveforms. Their unique combination of high performance over a broad frequency range and low cost make them the ideal choice for a broad spectrum of major markets:

Markets

- Communications Networks
 - Long Haul or Data Bus
 - Coaxial or Fiber Cable
- Communications Radios
 - HF, VHF, UHF
- Commercial or Military
- Satellite Ground Stations
- High Speed Facsimile
- Telemetry
- Radar
- ECM
- Instrumentation

Applications

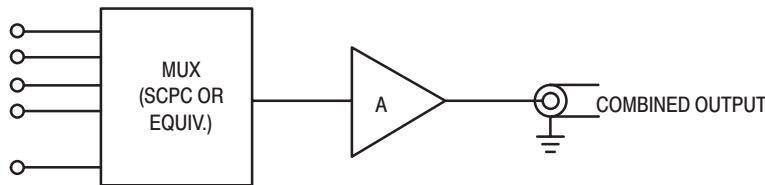
- Antenna Distribution
- Cable Drivers (50 Ω or 75 Ω)
- CCD Drivers
- IF Amplifiers
- Local Oscillator Buffers
- Repeater Amplifiers
- SAW Filter Amplifiers
- Signal Processing Equipment
- Swept Measurement Testing
- Transmitter Drivers

Key Features

- Linear Phase Response
- Wide Bandwidth, Low Distortion
- High Power Output Capability
- Unconditional Stability and Linear Operation into Highly Reactive Loads
- Infinite VSWR Protection
- High Third Order Intercept
- Excellent Impedance Match
- Low Noise Figure, Wide Dynamic Range

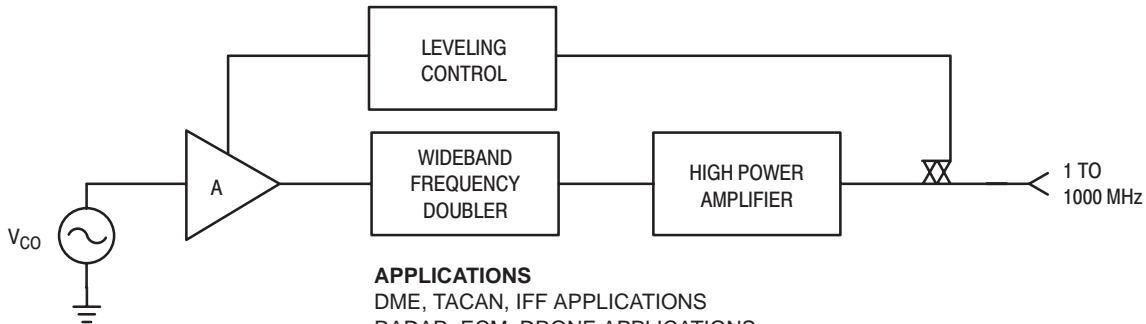
Freescale Semiconductor, Inc.

SATELLITE COMMUNICATIONS EQUIPMENT



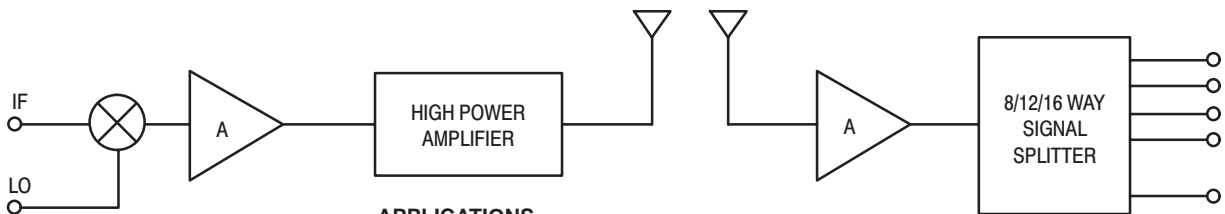
APPLICATIONS

- LINEAR POWER AMPLIFIER FOR FM, DIGITAL, DATA, OR VOICE CHANNELS
- DRIVER FOR EXTENDED LENGTHS OF COAX



APPLICATIONS

- DME, TACAN, IFF APPLICATIONS
- RADAR, ECM, DRONE APPLICATIONS
- BROADBAND SWEPT INSTRUMENTATION
- HF THROUGH UHF TRANSMITTER DRIVERS



TRANSMITTER DRIVER

APPLICATIONS

- HF, VHF, UHF FREQUENCY RANGE
- AM OR FM TRANSMISSION
- COMMERCIAL OR MILITARY EQUIPMENT
- N-WAY POWER SPLITTER

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Performance — The product of years of research, the RF linear hybrid offers the design engineer low distortion levels, wide dynamic range, and noise performance that are difficult to achieve in discrete form. This “extra margin” of performance may enhance the overall equipment design or allow more competitive specifications.

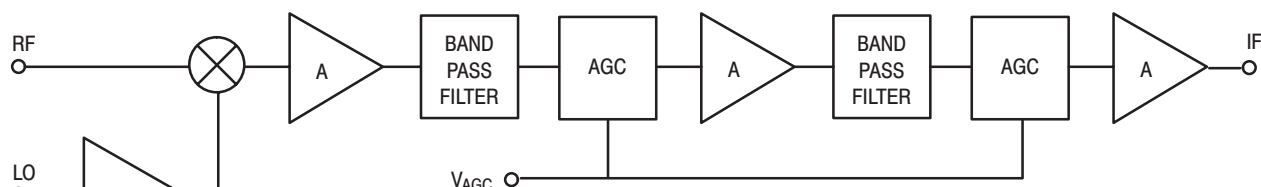
Size — If space is a consideration in the equipment design, the added real estate required for discrete circuitry may be prohibitive.

Reliability — The high degree of reliability demanded by the CATV industry has already been discussed. But given equivalent manufacturing and screening methods, hybrid circuits offer improved system reliability over a circuit comprised of multiple discrete components. This reliability improvement is a result of reduced package count, fewer solder interconnects (each interconnect is a potential failure point), and system level testing and screening performed by the hybrid manufacturer. Consequently the hybrid manufacturer. Consequently the hybrid manufacturer is accepting a larger responsibility for reliability. The delivered product is a combination of many discrete components tested as a complete system. Losses due to individual component interaction or failure are isolated during the manufacturing cycle.

Cost — The raw cost of materials to build a replacement discrete circuit for a particular application is usually less than the initial price of a hybrid. However, the following factors are often overlooked in many equipment designs:

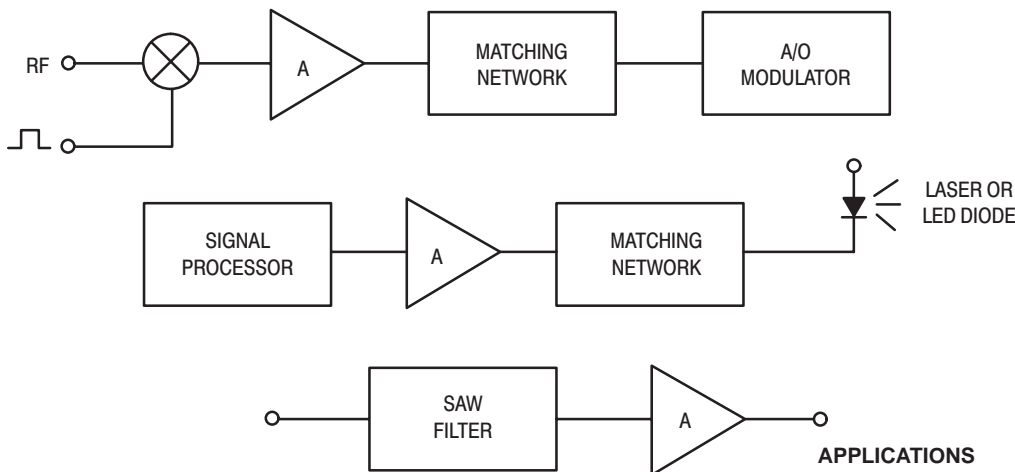
- a) The hybrid manufacturer is absorbing the costs of incoming inspection, assembly, and test on the circuit he is providing. Manufacturing costs for equipment using discrete circuitry are always higher than equivalent equipment utilizing commercially available hybrid circuits. This is especially true if any tuning or tweaking of the circuit is required.
- b) An equipment manufacturer's cost of procurement and cost of stocking are higher for a multicomponent discrete circuit than for a single thin film hybrid amplifier. These higher costs apply not only during the production build cycle, but throughout the lifetime of the equipment (spare parts inventory).
- c) Engineering costs to design reliable replacement circuit. Don't forget to include the time spent in debugging and optimizing the circuit, and the time spent in production support. The manufacturers of these RF linear hybrid amplifiers have spread their development costs over more than 1,000,000 units operating in the field.

HIGH PERFORMANCE RECEIVER APPLICATIONS



- APPLICATIONS**
 LINEAR IF AMPLIFIER
 BUFFER AMP FOR HIGH LEVEL MIXER
 REPEATER AMPLIFIER FOR FIBER OR COAXIAL CABLE COMMUNICATIONS
 HIGH DENSITY PACKAGING

ELECTRO/OPTICAL EQUIPMENT, SAW APPLICATIONS FIBER OPTIC APPLICATIONS



- APPLICATIONS**
 ACOUSTO-OPTIC MODULATORS
 FIBER OPTIC LASER/LED DRIVERS
 SAW FILTER AMPLIFIERS
 DRIVERS FOR CHARGE COUPLED DEVICES
 SUITABLE FOR ANALOG OR DIGITAL MODULATION, ALL TYPES OF WAVEFORMS

Is the RF Linear Hybrid The Right Choice For My Design?

In the end, the choice between a standard hybrid amplifier and a discrete circuit must be made by the design engineer. Find out what's available from the various manufacturers,

what their prices are, and what it costs your company to implement a discrete design. One thing you can be sure of: the thin film hybrid amplifiers described in this article have been proven in production and will be around for a long, long time. Probably longer than the discrete transistors they are replacing.

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