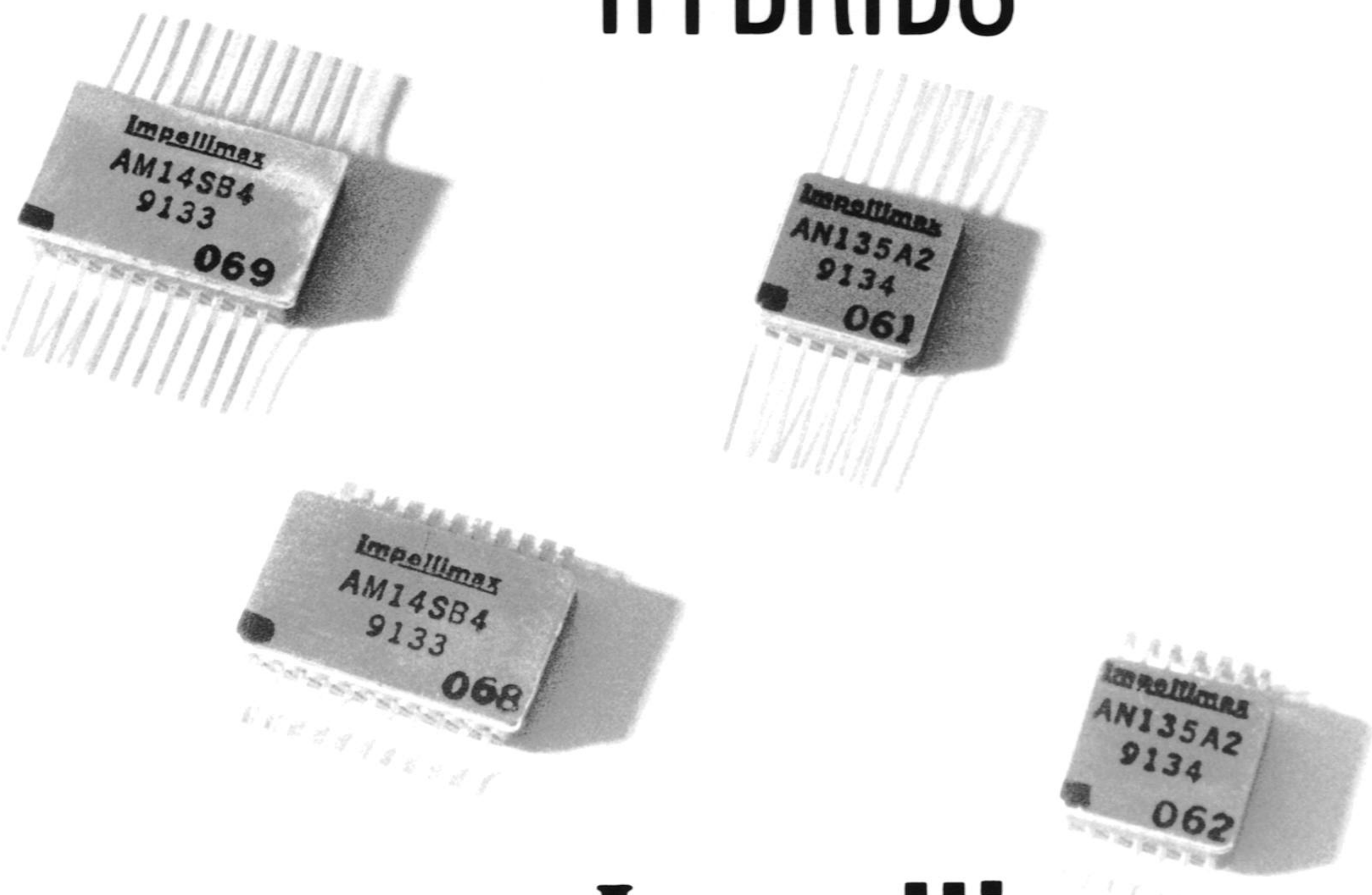
STANDARD LINEARIZER HYBRIDS



Impellimax

MICROWAVE DRIVERS

DESIGN GUIDE

IMPELLIMAX STANDARD LINEARIZER HYBRIDS

This design guide provides a general overview of some typical uses of Impellimax standard linearizers, along with connection diagrams, transfer functions, and measured performance data for the various modes of operation. Free software and Temperature-Precision linearizers are also discussed.

The four main applications covered in this note are as follows:

- PIN DIODE ATTENUATORS: Series, Shunt, Matched Shunt, Pi, T
- GaAs MMIC ATTENUATORS: Standard and Linear
- VARACTOR TUNED DEVICES: VCO's, Tuneable Filters, etc.
- TEMPERATURE COMPENSATION: Amplifiers and TCXO's

These linearizers are bipolar chip-and-wire hybrid circuits which can be delivered either as packaged or unpackaged units. Screening to MIL-STD-883 class B is available. Analog units consist of a high impedance analog input section, a linearizer with two to five active breakpoints, and a current source or sink output stage. Digital input types are available. Most models also contain an uncommitted current mirror to aid in certain applications, as will be seen later.

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IMPROVE PERFORMANCE AND PROFITABILITY

There are many performance benefits resulting from our hybrid circuit realization of this circuit. For example:

- All pairs of compensating transistor junctions are in very close proximity to each other. Semiconductors are strictly lot matched, and all resistors are 1% tolerance or tighter. As a result, drift over MIL temp ranges is small. Temperature-Precision type linearizers offer even greater stability, when such is necessary.

- Part-to-part uniformity is very tight, improving the profitability and limiting the risk inherent in linearized products.

- These hybrids are the smallest form of linearizer commercially available.

- Parasitics that can impair device performance absolutely minimized.

- Inventory and design complexity can be slashed. Training and testing time are reduced by simplifying and unifying diverse linearized products.

- Standard linearizers can produce simple or very complex transfer functions. Nonmonotonic curves are easily produced, as are S-shaped or multiple-S-shaped curves. Free software calculates breakpoint resistors and predicts system linearity directly from measured device data.

- Standard linearizers can be modified to fit your precise needs. Contact the factory to discuss the possibilities. This can result in great elegance of assembly, as complex PC boards can be replaced by a single, high-performance hybrid.

DRIVING PIN DIODE ATTENUATORS

PIN diode attenuators can be directly driven by the hybrid's current source or sink output. Typical topologies require the linearizer types given below:

Shunt PIN : Noninverting Concave Up

Shunt NIP : Mirrored Noninverting Concave

Series PIN : Mirrored Inverting Concave Down

Series NIP : Inverting Concave Down

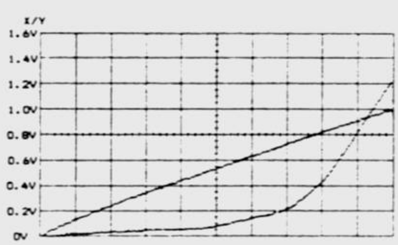
Connection drawings of two of these types are given in the figures. Independently biased series/shunt configurations can be accomodated as though they were independent series and shunt attenuators, with the appropriate driver styles chosen as given above.

Cascaded T or Pi sections frequently require two different bias levels for the outside elements relative to the inside one(s). This can most simply be achieved by using current split resistors on the output of the attenuator driver. More precision is achieved by using a separate linearizer for each required transfer function.

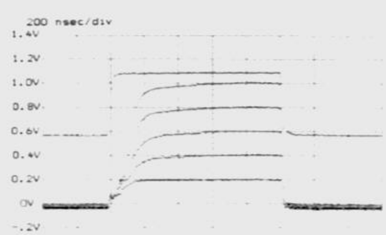
Typical bias currents for pin attenuators run in the range of 0 to 20 mA. Depending on supply voltages, this is within the output current capability of Impellimax Standard Linearizer Hybrids.

Switching performance of an uncompensated AN14UB4 driving a shunt 100 ohm resistor was evaluated. The transfer function was adjusted for 0 to 10 mA exponential rise of output current over a 0 to 10V input range . Small steps were settled in tens of nanoseconds, while a full-band step required 250 nsec to full positive and 100 nsec to 0 mA output. Proper selection of compensation could reduce these times substantially. Also, for best performance, breakpoint resistors should be connected with minimum parasitics, as close to the device as possible.

The transfer function was viewed over the temperature range of -55C to +125C and found to be quite stable. The typical shift of diode Rs over temperature is far greater than this, so that any temperature compensation that would be required is likely to be a function of diode characteristics, and not driver characteristics.

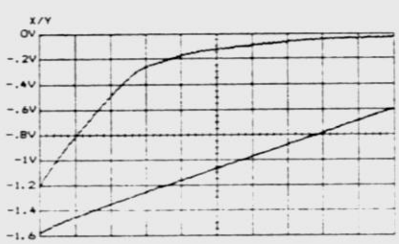


Typical Shunt PIN Transfer Function.
Current output is measured into 100 ohm load

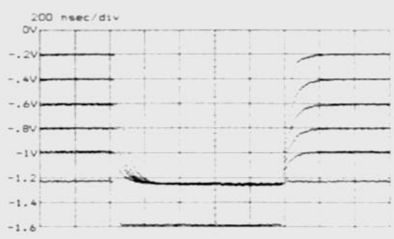


Uncompensated SettlingTime
Various Step Sizes

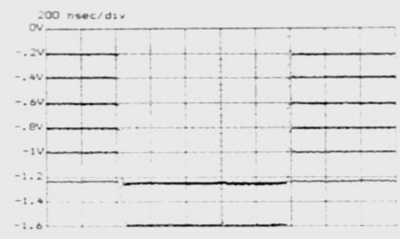
Compensated Settling Time
Various Step Sizes, 13 pF, 330 ohm



Typical Series PIN Transfer Function
Current output is measured into 100 ohm load



Uncompensated Settling Time
Various Step Sizes



Compensated Settling Time
Various Step Sizes, 13 pF, 330 ohm

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DRIVING GaAs MMIC ATTENUATORS

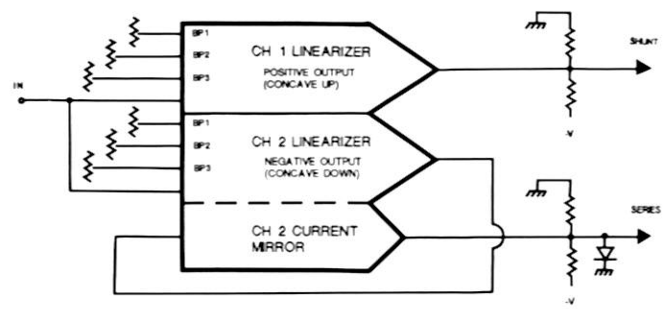
GaAs MMIC attenuators typically require two separate nonlinear voltage controls to provide linear, impedance-matched attenuation. The attached figure shows a typical set of such curves.

Impellimax standard linearizer hybrids are current-output devices, as described earlier in this note. By connecting the output to the midpoint of a resistive divider set between ground and -V, the voltage at this node produces the required voltage curve. See the attached connection diagram.

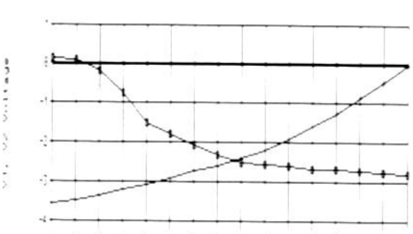
Some manufacturers and users of GaAs attenuators get improvements in power handling and reduced insertion loss by allowing the series FET gate bias to go slightly positive for low attenuation conditions. Fortunately, these curves, though fairly complex, are easily achieved with Standard Linearizer Hybrids.

As can be seen in the example schematic, these curves are generated by a dual linearizer hybrid, of the AM13SB4 type. These devices have two separate linearizers in one package, each with their associated current mirror. One output (used for the Shunt curve) provides a positive concave-up current which increases with increasing input voltage, while the other output is used with its' current mirror to provide a positive concave-up current which decreases with increasing input voltage. Both linearizers provide their output current into the center node of a resistive divider, as mentioned earlier. To produce the initial positive voltage and short-lived down-going curve seen at the low attenuation portion of the Series bias curve, the Series linearizer output current is tuned to produce a positive voltage intercept at 0 attenuation, and this voltage is clamped by a diode (or two in series, as necessary) to ground, giving rise to the final set of curves as shown in the figures.

If multiple MMIC's are used in an assembly, they can be driven by the same linearizer set, provided care is taken to maintain sufficient RF isolation in the shared bias lines.



Linearizer Connection Drawing, GaAs MMIC

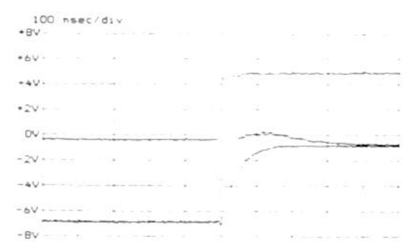


Typical GaAs MMIC Atten Curves

Data from MMIC vendor data sheets

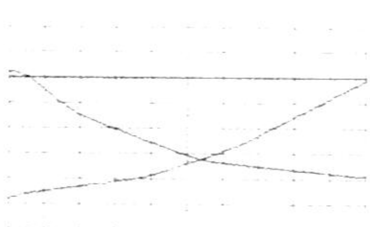
Voltage Settling Time, Shunt

Uncompensated vs 20 pF/1k Comp



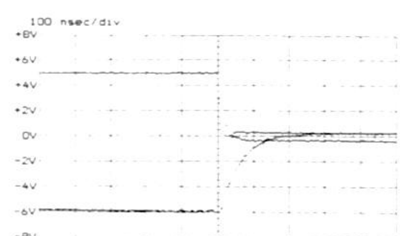
Voltage Settling Time, Shunt

Uncompensated vs 20 pF/1k Comp



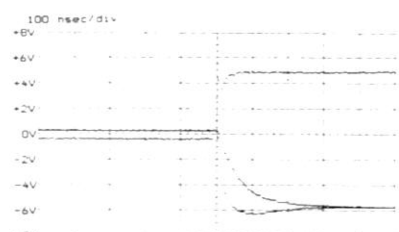
Curves Generated by Linearizer

Series curve shown with & without diode clipping



Voltage Settling Time, Series

Uncompensated vs 20 pF/1k Comp



Voltage Settling Time, Series

Uncompensated vs 20 pF/1k Comp

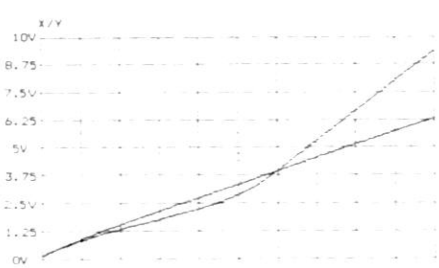
DRIVING VARACTOR-TUNED DEVICES

Linear tuning of varactor-tuned devices typically requires a single exponentially-curved control voltage, as shown in the figures. The following discussion will concern positive-voltage tuned devices, but it should be recognized that negative-tuning devices also exist, and similar, though inverted, procedures are used for these.

As can be seen in the connection diagram, the linearizer output provides concave-up non-inverting positive output current. The output of the linearizer is connected to the center node of a resistive divider. One end of the divider is connected to a positive voltage reference, and the other end is connected to ground. The resistors and the reference are chosen so that the open-circuit voltage of the center node is equal to the lowest required varactor tuning voltage. The output current from the linearizer drives this node voltage more positive with increasing input tuning voltage. This results in a voltage transfer function that can linearize varactor-tuned devices. The output resistor divider controls the offset and gain of the linearizer, and by varying these it is easy to tweak for each VCO in a lot.

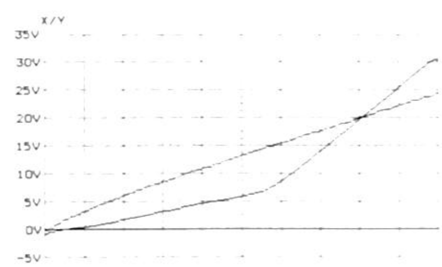
There are three voltage ratings available in the Standard Linearizer product line. The fastest version has 18 V output capability, providing typical settling times of 200 to 500 nsec for a full-band step. Where higher tuning voltages are required, the 40 V variety provides typical settling times of approximately 500 nsec to 1 usec. Standard Linearizer Hybrids with 100 V output capability require up to 2 usec for complete settling in a full-band step. These settling times are given as measured without compensation. Proper selection of compensation can substantially reduce settling time in most cases.

The output of a Standard Linear Hybrid is of moderately high impedance, so that accidental short circuits to ground will not damage the unit. When the varactor tuning path is of high capacitance, though, this high impedance can result in poor settling times. This is especially true if 'filter-conns' are involved in the varactor tuning port wiring. If this presents a problem in your application, contact the factory. Modified linearizers are available with output voltage buffers, to reduce the output impedance. This results in a lack of short-circuit protection, however, so the trade-offs should be thoroughly considered.



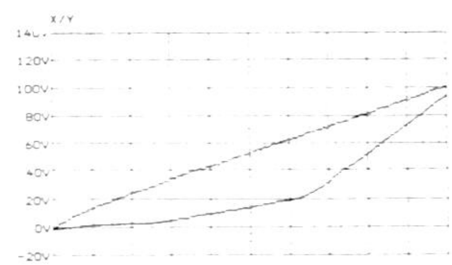
Voltage Output Trans Function

Low Voltage, High Speed Applications



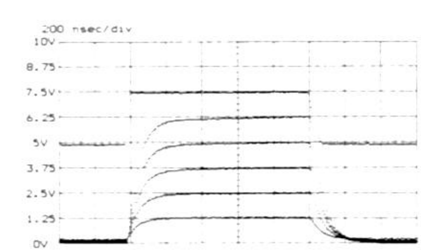
Voltage Output Transfer Function

Moderate Voltage, Medium Speed Appplications



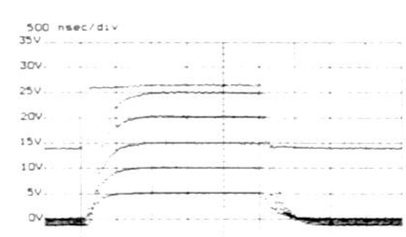
Voltage Output Transfer Function

High Voltage, Moderate Speed Applications



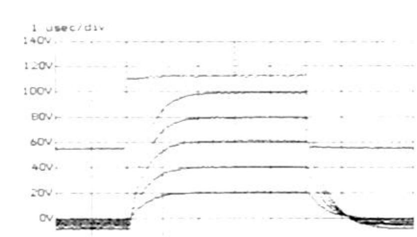
Current Output Trans Funct, Series

Current output is measured into 100 ohm



Voltage Settling Time, Series

Uncompensated vs 20 pF/1k Comp



Voltage Settling Time, Series

Uncompensated vs 20 pF/1k Comp

TEMPERATURE COMPENSATION OF RF DEVICES

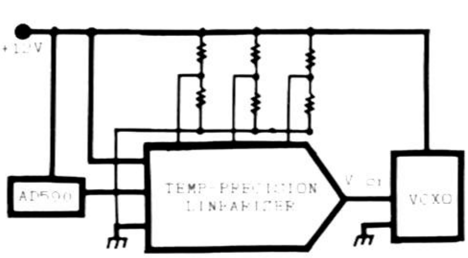
Many microwave devices could benefit from a correction voltage or current that is a function of temperature. For example, amplifier gain, detector sensitivity, and oscillator frequency can be stabilized to near-perfection with a temperature-driven linearizer circuit.

The first step in this process is to experimentally determine the required current or voltage vs. temperature curve to provide optimum temperature stabilization. This data, along with design goal tolerances on stability, helps to determine what type of linearizer will be best for the job. Simple applications can be handled by standard linearizers. More demanding aplications, such as tight-tolerance TCXO's, are best handled by Temperature-Precision linearizers.

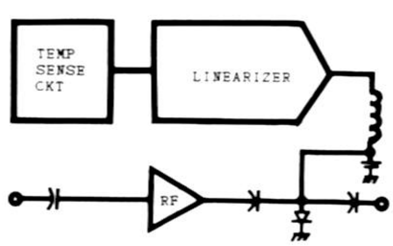
A brief comparison of Standard and Temperature-Precision (TP) linearizers will help make the determination more clear. TP linearizers use a reference junction and feedback system to make the performance of the linearizer more stable and mathematically predictable. For example, a standard linearizer connected to generate a 0 to 10 volt curve will drift about +/- 5% over the -55 to +125 C temperature range, while a TP linearizer will typically remain within +/-1% of room temperature values. Also, software predictions using TP linearizers are typically within 50 mV of measured data, while a standard linearizer can only be expected to be within about 250 mV of software predictions. TP linearizers can be directly driven by 1 uA/K temp-sensor IC's such as the AD590. This makes the system very precise and predictable. Alternatively, both standard and TP linearizers can be driven directly by thermistors or op-amp circuits. TP linearizers have a short-circuit protected voltage output, while the output of a standard linearizer is a current. TP linearizers cost about 10% more than standard linearizers, and their settling time is slower.

The diagrams below show only a few of the ways in which linearizer hybrids can bring near-perfect temperature stability to RF and microwave devices.

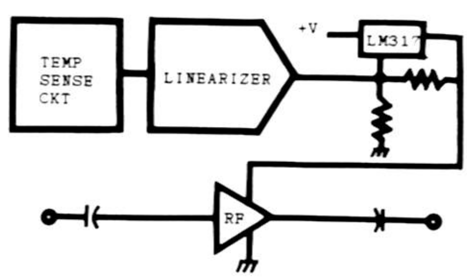
Please see page 7 of this design guide for recommendations on temperature-stabilizing systems that already incorporate a linearizer, such as linearized attenuators and VCO's.



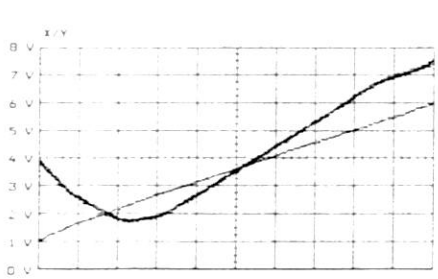
Temp-Precision TCXO Stabilization
Can also use thermistor as sensor



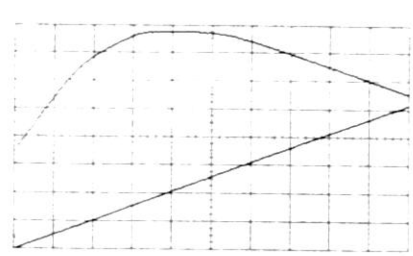
Amplifier Temp Comp of Gain
One of several possible methods



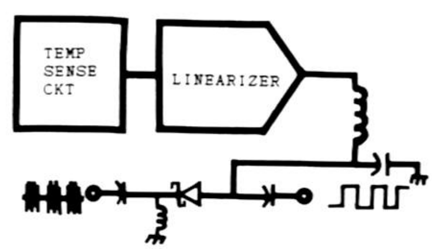
Generating Nonlinear Bias vs Temp
Provide tuneable, optimal performance vs Temp



Typical TCXO Crrection Curve
Generated by circuit as shown in upper figure

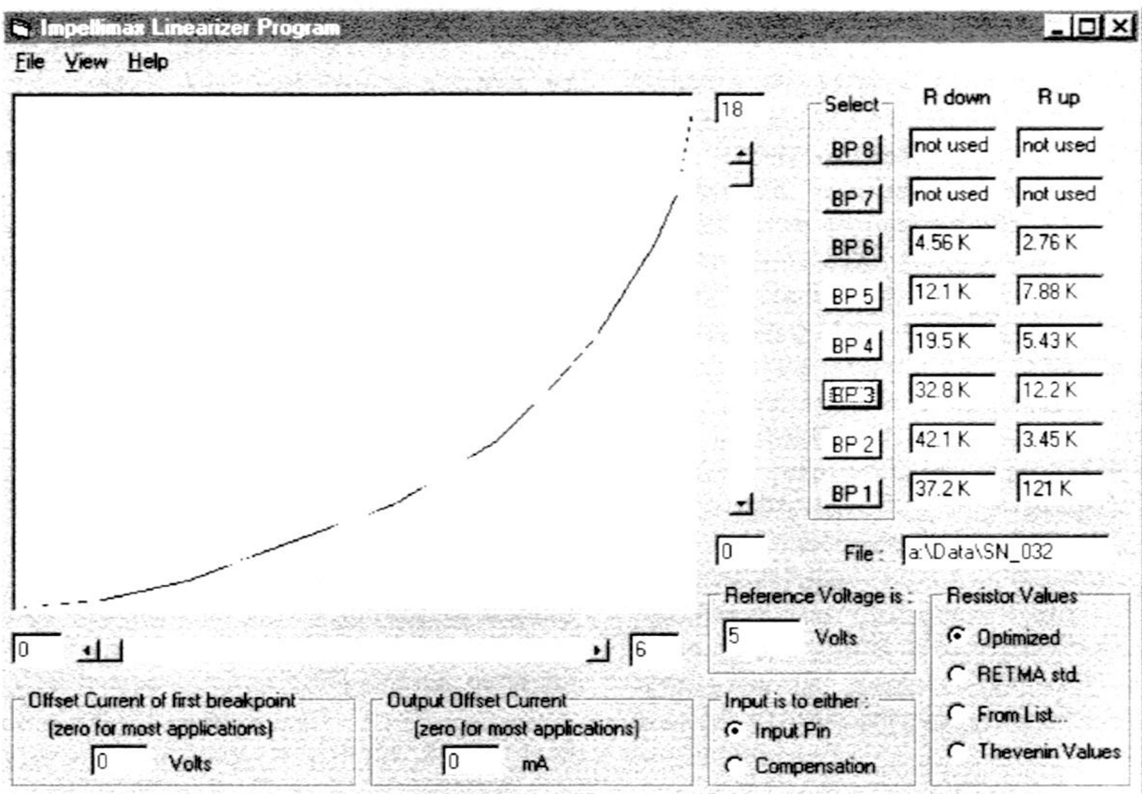


Hump Shaped Output vs Temp
Other curvatures are also easily generated



Bias Current for Detector Diode
Stabilize and optimize sensitivity vs temp

SOFTWARE FOR CALCULATION OF BREAKPOINT RESISTORS



Impellimax provides free Windows 95^{tm} compatible software to aid in the use of linearizers. Program disks are available upon request, or the program can be downloaded from our website at www.Impellimax.com .

This program accepts data on your device (from a spreadsheet, database, text file, or manual data entry) and plots the device data. Simple interactive controls allow you to graphically align breakpoint straight-line segments to the data. The program continuously calculates the required resistor values and displays them in color-coded fields to the right of the display area. Resistor values can also be directly inputted into these fields, which in turn adjusts the graphical view accordingly.

Resistor values can be listed as optimized values, or they can be constrained to follow either RETMA standard value listings or your own inventoried resistor values.

Print, Open, and Save commands allow you to preserve data from previous sessions, select data files for linearization, and document your design for future reference.

Internal laser-trimmed resistors can now be incorporated within the linearizer package, as a semi-custom option that can radically simplify your designs. Contact the factory for details.

SOME ITEMS OF INTEREST IN THE USE OF LINEARIZERS

INPUT CHARACTERISTICS AND COMPENSATION

Standard Hybrid Linearizers present a 15 Kohm impedance at the input pin when operating. This drops to 7.5 Kohm without power. The compensation input presents a 7.5 Kohm load when operating, and a very low impedance without power.

In general, use the input pin when the tuning input is greater than 3 volts in range, or whenever settling time compensation is expected to be necessary. The compensation pin can be used as tuning input for narrow tune voltage applications where speed is noncritical and the 7.5 Kohm input impedance is acceptable.

Temperature Precision linearizers present a 20 Kohm impedance when operating, and a low impedance without power.

VOLTAGE REFERENCES

Frequent mention is made in this design guide of the use of reference voltages. They are primarily required in setting up breakpoint voltages by use of resistive dividers. In general, any reference voltage will do, provided that it is of correct polarity and magnitude to enable the breakpoint voltages to be created. Contact the factory if you have any uncertainty, but in general, references are called upon to provide an output current which is slightly greater than the maximum output current that will be drawn from the linearizer. Noise and drift present on the reference supply will typically couple through to the output of the linearizer, so care should be taken to keep the reference quiet and stable.

CURRENT MIRRORS : WHAT THEY DO AND HOW TO USE THEM

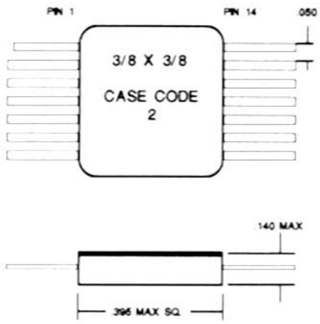
A Standard Linearizer current mirror consists of lot-matched transistors and precision resistors that accurately converts a current sink into a current source, or vice versa.

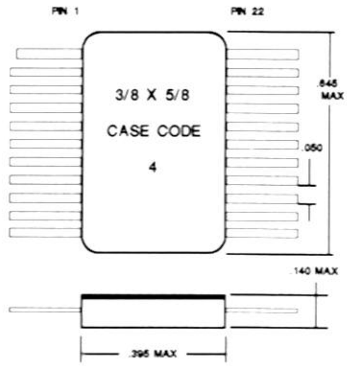
For example, If a series diode PIN attenuator is set up to take negative current, a negative concave-up linearizer will work fine. But if the series PIN is rotated so that positive current is required instead, the negative current provided by the linearizer ouput could simply be connected to the associated current mirror input pin. The current mirror output would then be suitable for linearizing the attenuator. The output current transfer function of the resulting linearizer/current mirror combo is the exact reflection (about the zero-current line) of the transfer function of the linearizer alone. Hence the term "Current Mirror".

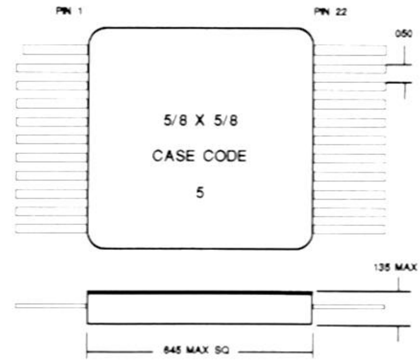
Current mirrors can also be used to provide fixed offset currents that can be tied directly to a linearizer output. Connect a resistor from the current mirror input pin to ground or +Vref, as required, to establish a fixed input current for the mirror. The mirror output is then a temperature-stable current source (or current sink) that can be summed with linearizer outputs.

Application notes are available with more thorough treatment of curve synthesis and current mirrors.

MECHANICAL DRAWINGS AND PIN-OUTS





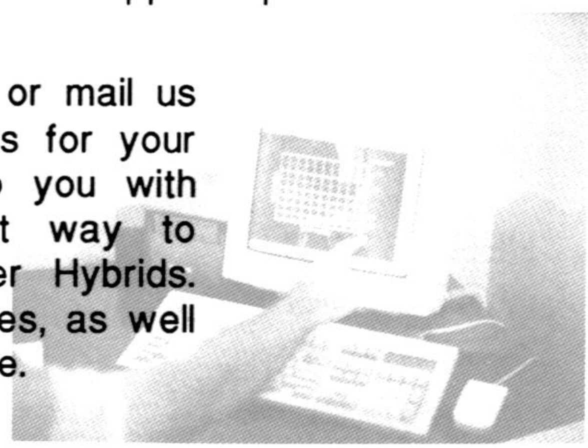


PIN #	One Channel 3/8x3/8	One Chan High Volt 3/8x3/8	Two Chan No Mirror 3/8x3/8	One Chan (HiV/9BP) 3/8x5/8	One Chan Vref (HV) 3/8x5/8	Two Chan (Hi Volt) 3/8x5/8	DAC input 1chan(HV) 5/8x5/8
1	-V	-V	-V	+V	+V	+V	+V
2	OUT	OUT	NEG OUT	INPUT	INPUT	POS IN	BIT 1(MSB)
3	GND	GND	GND	COMP	COMP	COMP	BIT 2
4	INPUT	INPUT	NEG IN	BP1	BP1	POS BP1	BIT 3
5	COMP	COMP	POS IN	BP2	BP2	POS BP2	BIT 4
6	NC	Rext	POS OUT	BP3	BP3	POS BP3	BIT 5
7	+V	+V	+V	BP4	BP4	POS BP4	BIT 6
8	BP1	BP1	POS BP1	MIRR OUT	MIRR OUT	PMIR OUT	BIT 7
9	BP2	BP2	POS BP2	LIN OUT	LIN OUT	PLIN OUT	BIT8(LSB)
10	NC	MIRR IN	POS BP3	MIRR IN	MIRR IN	PMIR IN	DACLINTP
11	BP3	BP3	NC	-V	-V	-V	-V
12	NC	MIRR OUT	NEG BP1	GND	GND	GND	GND
13	BP4	BP4	NEG BP2	NC	NC	NMIR IN	MIRR IN
14	BP5	BP5	NEG BP3	NC	REF OUT	NLIN OUT	LIN OUT
15	*	*	*	NC	NC	NMIR OUT	MIRR OUT
16	*	*	*	NC(BP5)	NC	NEG BP4	BP1
17	*	*	*	NC(BP6)	NC	NEG BP3	BP2
18	*	*	*	NC(BP7)	NC	NEG BP2	BP3
19	*	*	*	NC(BP8)	NC	NEG BP1	BP4
20	*	*	*	NC(BP9)	NC	COMP	BP5
21	*	*	*	NC	NC(Vtp)	NEG IN	+VrefDAC
22	*	*	*	NC(Rext)	NC(Rext)	NC(Rext)	NC(Rext)

The pin-outs listed above are a representative sampling of the diverse range of devices possible within the Standard Linearizer Hybrid format. Alternative pin-outs, special functions, non-standard packages, and open-substrate versions are also readily available, to best suit your applications.

INFORMATION BY PHONE: Sometimes a simple discussion with an applications engineer can help move your concept to reality quickly. Feel free to call anytime.

BREAKPOINT MINI-BOARDS: Printed circuit boards are available which mate up along one side of our Standard Linearizer Hybrid packages. Leads solder directly to mating pads, and they have a conductor pattern for breakpoint resistors and a surface mount voltage reference IC. Artworks are available for fixed resistor and potentiometer versions. They are less than an inch square and are set up with mounting holes, so in most cases they can go right into your shippable product.



TRANSFER FUNCTION SYNTHESIS: Fax or mail us a graph of the input vs output requirements for your linearizer project and we will get back to you with specific recommendations on the simplest way to achieve your goal with Standard Linearizer Hybrids. Please indicate supply voltages and tolerances, as well as specifications on final linearity, if applicable.

TEST TO YOUR CURVE: We can quickly configure our test stand to your particular voltages and breakpoint values, allowing us to verify your calculations and fax back a measured graph of the resulting transfer function. Then, along with our standard testing, we can use this graph as a correlation standard to check each shipped hybrid in the same way you will use them.

CUSTOMIZED 'STANDARDS': We can easily and quickly create a special linearizer that best fits your needs. Special packaging, internal voltage references, digital inputs, and laser-trimmed internal breakpoint resistors are just some of the many options we can incorporate to make the best solution for you.

RESISTOR CALCULATION SOFTWARE: We are offering free software that calculates the breakpoint resistors needed to synthesize any realizeable transfer function your application requires. Executable program disks and BASIC listings are available, no purchase required.

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A FULL-LINE MANUFACTURER OF MIL-SPEC AND COMMERCIAL HYBRID CIRCUITS FOR USE IN MICROWAVE CONTROL DEVICES

- PIN DIODE SWITCH DRIVERS
- GaAs MMIC SWITCH DRIVERS
- STANDARD LINEARIZER HYBRIDS
- YIG, IMPATT, & LASER DRIVERS
- MINIATURE HEATER MODULES

HERE'S SOME FINE PRINT ABOUT IMPELLIMAX:

* Complete capability from R&D thru prototypes to production * Volumes from 1 to 10,000 pieces per order * NRE almost never required * Processing and systems compliant to MIL-STD-883, MIL-M-38510, MIL-STD-45208 * Certification to MIL-STD-1772 is in process * Assembly area is class 100K, with humidity, temperature, and particle count measured and recorded daily * Complete ESD program in place including faraday cage sealed kit trays * Nitrogen atmosphere glove box for seal and other solder operations * Surface mount gull-wing lead forming, with fine and gross seal tests performed after lead form * In-house layout, photofab, assembly, and test for quick first-lot deliveries * 100% nondestruct bondpull available, with printed output * Low cost * Computerized price and delivery quotation - no wasted time * Dry nitrogen storage * Experienced and motivated staff * Quality program per MIL-Q-9858 * Die shear * Residual Gas Analysis certification of processes * Traceable lot qualification on all elements * 2.5 mil lines and spaces standard for compact high density layouts * Drivers shipped in packages or as open substrates * Drivers built into RF housings * Computerized automatic test data available * Dry nitrogen burn-in ovens for pre-seal burn-in *Gold-germanium solder submount available * And more...

AND SOME MORE FINE PRINT, ABOUT DRIVERS:

Some technical highlights include: 32 channel decoded PIN driver with ultra- low dissipation * ECL high speed 100V dual driver * Laser diode driver with 300 MHz PRF and bias and modulation controls * Drivers with two outputs per channel for filter banks, etc * PIN driver output currents from 1 to 600 mA per channel * TTL line receiver inputs * Decoded GaAs MMIC driver * GaAs drivers set up for driving individual RF FETS * Dual 120V TTL PIN driver with BIT outputs to signal driver or diode failures * Overvoltage and reverse-voltage protected drivers survive +/-30V on a +/-5V part * Single analog input controls three channel driver in tiny package * GaAs drivers with zero time skew for low transient switching * Eight independent CMOS compatible PIN drivers in a 3/8 by 5/8 inch package * Substrate drivers designed to drop into small RF modules * TTL input that selects fast or slow switching from the same driver * TTL compatible input with +4 to +8 volts as positive supply * Six independent 100V high speed drivers with TTL input that forces outputs positive when negative supply is not present * Two-chip set decodes 8 bit TTL to sixteen lines of GaAs control voltages * High speed high voltage drivers with short-circuit protected outputs * Internal high-current +5V regulators and more, more , more ...

...AND ALL THE FINE PRINT IS GOOD !

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LDC100 Rev A