

Pulse-Width Modulating Regulator

GENERAL DESCRIPTION

The XR-1524 family of monolithic integrated circuits contain all the control circuitry for a regulating power supply inverter or switching regulator. Included in a 16-pin dual-in-line package is the voltage reference, error amplifier, oscillator, pulse width modulator, pulse steering flip-flop, dual alternating output switches and current limiting and shut-down circuitry. This device can be used for switching regulators of either polarity, transformer coupled DC to DC converters, transformerless voltage doublers and polarity converters, as well as other power control applications. The XR-1524 is specified for operation over the full military temperature range of -55°C to $+125^{\circ}\text{C}$, while the XR-2524 is specified to operate from -25°C to $+85^{\circ}\text{C}$. The XR-3524 are designed for commercial applications of 0°C to $+70^{\circ}\text{C}$.

FEATURES

- Pin-for-Pin Replacement for SG-1524/2524/3524
- Complete PWM power control circuitry
- Single ended or push-pull outputs
- Line and load regulation of 0.2%
- 1% maximum temperature variation
- Total supply current less than 10 mA
- Operation beyond 100 kHz

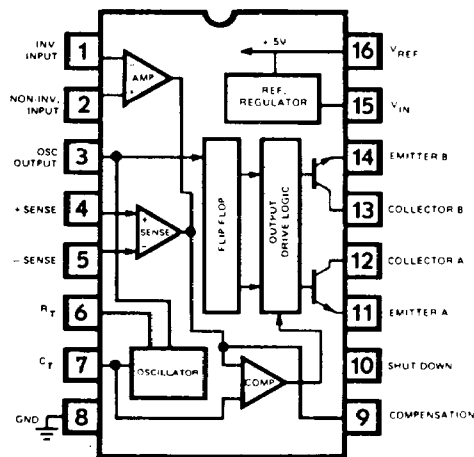
APPLICATIONS

- Switching Regulators
- Pulse-width Modulated Power Control Systems

ABSOLUTE MAXIMUM RATINGS

Input Voltage	40V
Output Current (each output)	100 mA
Reference Output Current	50 mA
Oscillator Charging Current	5 mA
Power Dissipation	
Ceramic Package	1000 mW
Derate above $+25^{\circ}\text{C}$	8 mW/ $^{\circ}\text{C}$
Plastic Package	625 mW/ $^{\circ}\text{C}$
Derate above $+25^{\circ}\text{C}$	5 mW/ $^{\circ}\text{C}$
Japanese SO	500 mW
Derate above 25°C	5 mW/ $^{\circ}\text{C}$
Operating Temperature Range	
XR-1524	-55°C to $+125^{\circ}\text{C}$
XR-2524/XR-3524	0°C to $+70^{\circ}\text{C}$
Storage Temperature Range	-65°C to $+150^{\circ}\text{C}$

FUNCTIONAL BLOCK DIAGRAM



ORDERING INFORMATION

Part Number	Package	Operating Temperature
XR-1524M	Ceramic	-55°C to $+125^{\circ}\text{C}$
XR-2524N	Ceramic	-25°C to $+85^{\circ}\text{C}$
XR-2524P	Plastic	-25°C to $+85^{\circ}\text{C}$
XR-3524CN	Ceramic	0°C to $+70^{\circ}\text{C}$
XR-3524CP	Plastic	0°C to $+70^{\circ}\text{C}$
XR-3524MD	Japanese Dimension SO-16	0°C to $+70^{\circ}\text{C}$

SYSTEM DESCRIPTION

The XR-1524/2524/3524 pulse width modulating regulator is a complete monolithic switching regulator. An internal 5V reference, capable of supplying up to 50 mA to external loads, provides an on board operating standard. The oscillator frequency and duty cycle are adjusted by an external RC network. Regulation is controlled by an error amplifier which, combined with the sense amplifier, also allows current limiting and remote shutdown functions. The outputs of the XR-1524/2524/3524 are two identical NPN transistors with both emitters and collectors uncommitted. Each output transistor has antisaturation circuitry for fast response and local current limiting set at 100 mA.

ELECTRICAL SPECIFICATIONS

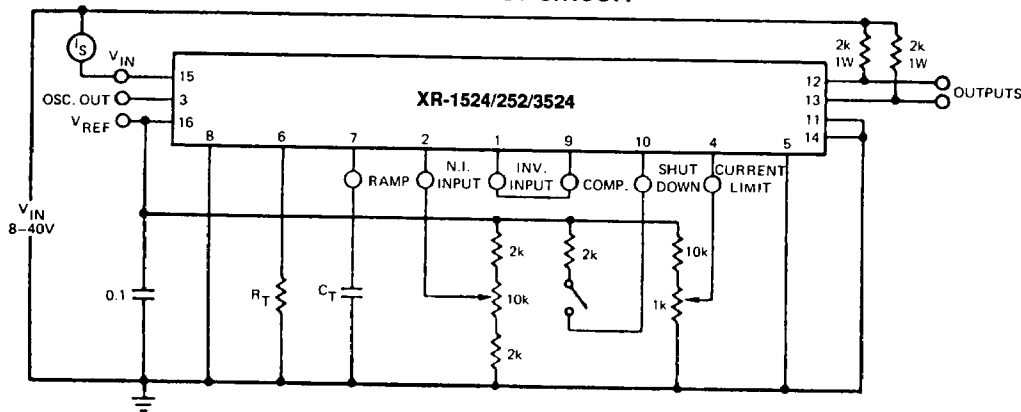
Test Conditions: $T_A = 25^\circ\text{C}$ $V_{IN} = 20\text{V}$, and $f = 20\text{ kHz}$, unless specified otherwise.

PARAMETERS		XR-1524/ XR-2524			XR-3524			UNITS	CONDITIONS
		MIN	TYP	MAX	MIN	TYP	MAX		
REFERENCE SECTION									
Output Voltage	4.8	5.0	5.2	4.6	5.0	5.4	V	$V_{IN} = 8$ to 40 Volts $I_L = 0$ to 20 mA $f = 120$ Hz, $T_A = 25^\circ\text{C}$ $V_{REF} = 0$, $T_A = 25^\circ\text{C}$ Over Operating Temperature Range* $T_A = 25^\circ\text{C}$	
Line Regulation		10	20		10	30	mV		
Load Regulation		20	50		20	50	mV		
Ripple Rejection		66			66		dB		
Short Circuit Current Limit		100	150		100		mA		
Temperature Stability		1.0	2		0.3	1	%		
Long Term Stability		20			20		mV/kyr		
OSCILLATOR SECTION									
Maximum Frequency		300			300		kHz	$C_T = .001\text{ }\mu\text{F}$, $R_T = 2\text{ K}\Omega$ R_T and C_T constant $V_{IN} = 8$ to 40 Volts, $T_A = 25^\circ\text{C}$ Over Operating Temperature Range* Pin3, $T_A = 25^\circ\text{C}$ $C_T = .01\text{ mfd}$, $T_A = 25^\circ\text{C}$	
Initial Accuracy		5			5		%		
Voltage Stability			1			1	%		
Temperature Stability			2		2		%		
Output Amplitude		3.5			3.5		V		
Output Pulse Width		0.5			0.5		μS		
ERROR AMPLIFIER SECTION									
Input Offset Current			2		2		μA	$V_{CM} = 2.5$ Volts $V_{CM} = 2.5$ Volts $T_A = 25^\circ\text{C}$ $T_A = 25^\circ\text{C}$ $A_V = 0$ dB, $T_A = 25^\circ\text{C}$ $T_A = 25^\circ\text{C}$	
Input Offset Voltage		0.5	5		2	10	mV		
Input Bias Current		2	10		2	10	μA		
Open Loop Voltage Gain	72	80		60	80		dB		
Common Mode Voltage	1.8		3.4	1.8		3.4	V		
Common Mode Rejection Ratio	46	70			70		dB		
Small Signal Bandwidth		3			3		MHz		
Output Voltage	0.5		3.8	0.5		3.8	V		
COMPARATOR SECTION									
Duty Cycle	0		45	0		45	%	% Each Output On Zero Duty Cycle Max. Duty Cycle	
Input Threshold		1			1		V		
Input Threshold		3.5			3.5		V		
Input Bias Current		1			1		μA		
CURRENT LIMITING SECTION									
Sense Voltage	190	200	210	180	200	220	mV	Pin 9 = 2V with Error Amplifier Set for Max. Out, $T_A = 25^\circ\text{C}$	
Sense Voltage Temp. Coef.		0.2			0.2		mV/ $^\circ\text{C}$		
Common Mode Voltage	-0.3		+0.3	-0.3		+0.3	V		
OUTPUT SECTION (Each Output)									
Max. Collector-Emitter Voltage	40			40			V	$V_{CE} = 40\text{V}$ $I_C = 50\text{ mA}$ $V_{IN} = 20\text{V}$ $R_C = 2\text{ K}\Omega$, $T_A = 25^\circ\text{C}$ $R_C = 2\text{ K}\Omega$, $T_A = 25^\circ\text{C}$	
Collector Leakage Current		0.1	50		0.1	50	μA		
Saturation Voltage		1	2		1	2	V		
Emitter Output Voltage	17	18		17	18		V		
Rise Time		0.2			0.2		μS		
Fall Time		0.1			0.1		μS		
TOTAL STANDBY CURRENT									
(Excluding oscillator charging current, error and current limit dividers, and with outputs open)		8	10		8	10	mA	$V_{IN} = 40\text{V}$	

* These parameters, although guaranteed over the recommended operating conditions, are not 100% tested in production.

XR-15/25/3524

OPEN LOOP TEST CIRCUIT



DESCRIPTION OF CIRCUIT OPERATION

VOLTAGE REFERENCE SECTION

The internal voltage reference and regulator section provides a 5-volt reference output at pin 16. This voltage also serves as a regulated voltage source for the internal timing and control circuitry. This regulator may be bypassed for operation from a fixed 5-volt supply by connecting pins 15 and 16 together to the input voltage. In this configuration, the maximum input voltage is 6.0 volts.

This reference regulator may be used as a 5-volt source for other circuitry. It will provide up to 50 mA of current itself and can easily be expanded to higher currents with an external PNP as shown in Figure 2.

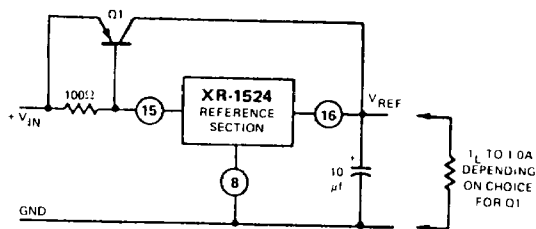


Figure 2. Using the Internal Regulator as 5V Power Supply for External Circuitry

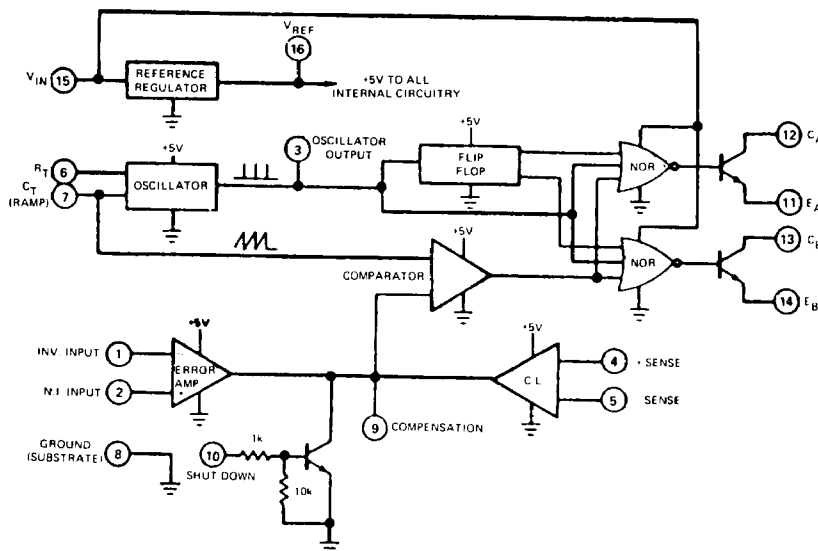


Figure 1. Detailed System Block Diagram of XR-1524

OSCILLATOR SECTION

The oscillator section in the XR-1524 uses an external resistor (R_T) to establish a constant charging current into an external capacitor (C_T). While this uses more current than a series connected RC, it provides a linear ramp voltage on the capacitor which is also used as a reference for the comparator. The charging current is equal to $3.6V \div R_T$ and should be kept within the range of approximately $30 \mu A$ to 2 mA , i.e., $1.8K < R_T < 100K$.

The oscillator period is approximately $T = R_T C_T$ where T is in microseconds when $R_T = \text{ohms}$ and $C_T = \text{microfarads}$.

The use of Figure 3 allows the selection of R_T and C_T for a wide range of operating frequencies. Note that for series regulator applications, the two outputs can be connected in parallel for an effective 0 – 90% duty cycle and the frequency of the oscillator is the frequency of the output. For push-pull applications, the outputs are separated and the flip-flop divides the frequency such that each output's duty cycle is 0 – 45% and the overall frequency is 1/2 that of the oscillator.

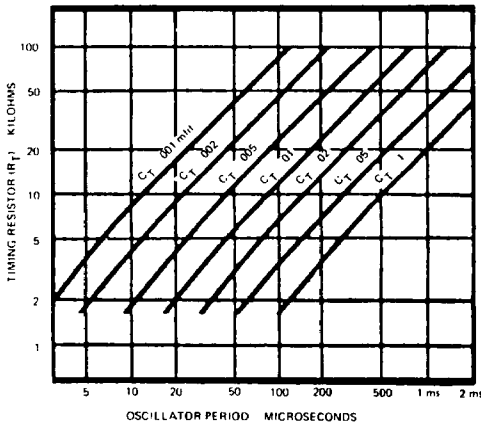


Figure 3. Oscillator Period as a Function of R_T and C_T

The range of values for C_T also has limits as the discharge time of C_T determines the pulse width of the oscillator output pulse. This pulse is used (among other things) as a blanking pulse to both outputs to insure that there is no possibility of having both outputs on simultaneously during transitions. This output dead time relationship is shown in Figure 4. A pulse width below approximately 0.5 microseconds may allow false triggering of one output by removing the blanking pulse prior to the flip-flop's reaching a stable state. If small values of C_T must be used, the pulse width may still be expanded by adding a shunt capacitance ($\approx 100 \text{ pF}$) to ground at the oscillator output. (Note: Although the oscillator output is a convenient oscilloscope sync input, the cable and input capacitance may increase the blanking pulse width slightly.) The upper limit to the pulse width is determined by the maximum duty cycle acceptable. Practical values of C_T fall between $.001$ and $0.1 \mu F$.

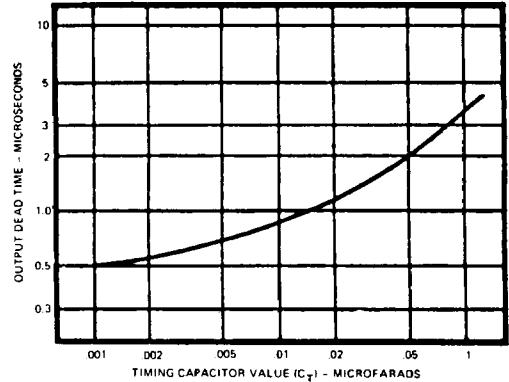


Figure 4. Output Stage Dead Time as a Function of the Timing Capacitor Value

If it is desired to synchronize the XR-1524 to an external clock, a pulse of $\approx +3$ volts may be applied to the oscillator output terminal with $R_T C_T$ set slightly greater than the clock period. The same considerations of pulse width apply. The impedance to ground at this point is approximately $2K \text{ ohms}$.

If two or more XR-1524 circuits must be synchronized together, one must be designated as master with its $R_T C_T$ set for the correct period. The slaves should each have an $R_T C_T$ set for approximately 10% longer period than the master with the added requirement that $C_T (\text{slave}) = 1/2 C_T (\text{master})$. Then connecting pin 3 on all units together will insure that the master output pulse – which occurs first and has a wider pulse width – will reset the slave units.

ERROR AMPLIFIER SECTION

The error amplifier is a simple differential-input, trans-conductance amplifier. The output is the compensation terminal, pin 9, which is a high-impedance node ($R_L \approx 5 \text{ M}\Omega$). The gain is

$$A_v = g_m R_L = \frac{8 I_C R_L}{2kT} \approx .002 R_L$$

and can easily be reduced from a nominal of 10,000 by an external shunt resistance from pin 9 to ground, as shown in Figure 5.

In addition to DC gain control, the compensation terminal is also the place for AC phase compensation. The frequency response curves of Figure 5 show the uncompensated amplifier with a single pole at approximately 200 Hz and a unity gain cross-over at 5 MHz.

Typically, most output filter designs will introduce one or more additional poles at a significantly lower frequency. Therefore, the best stabilizing network is a series R-C combination between pin 9 and ground which introduces a zero to cancel one of the output filter poles. A good starting point is $50 K\Omega$ plus $.001 \mu F$.

XR-15/25/3524

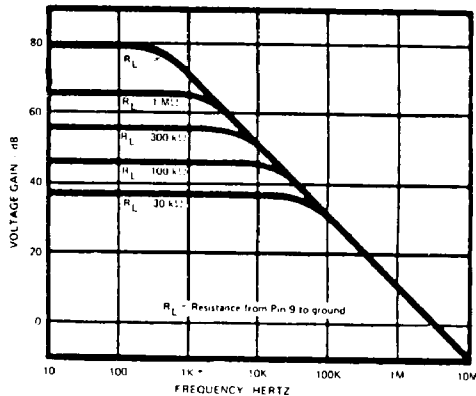


Figure 5. Error Amplifier Frequency Response as a Function of External Resistor, R_L , at Pin 9

One final point on the compensation terminal is that this is also a convenient place to insert any programming signal which is to override the error amplifier. Internal shutdown and current limit circuits are connected here, but any other circuit which can sink $200 \mu\text{A}$ can pull this point to ground, thus shutting off both outputs.

While feedback is normally applied around the entire regulator, the error amplifier can be used with conventional operational amplifier feedback and is stable in either the inverting or non-inverting mode. Regardless of the connections, however, input common-mode limits must be observed or output signal inversions may result. For conventional regulator applications, the 5-volt reference voltage must be divided down as shown in Figure 6. The error amplifier may also be used in fixed duty cycle applications by using the unit gain configuration shown in the open loop test circuit.

CURRENT LIMITING CONTROLS

The current limiting circuitry of the XR-1524 is shown in Figure 7.

By matching the base-emitter voltages of Q1 and Q2, and assuming negligible voltage drop across R_1 ,

$$\text{Threshold} = V_{BE}(Q1) + I_1 R_2 - V_{BE}(Q2) = I_1 R_2 \approx 200 \text{ mV}$$

Although this circuit provides a relatively small threshold with a negligible temperature coefficient, there are some limitations to its use, the most important of which is the ± 1 volt common mode range which requires sensing in the ground line. Another factor to consider is that the frequency compensation provided by $R_1 C_1$ and Q1 provides a roll-off pole at approximately 300 Hertz.

Since the gain of this circuit is relatively low, there is a transition region as the current limit amplifier takes over pulse width control from the error amplifier. For testing purposes, threshold is defined as the input volt-

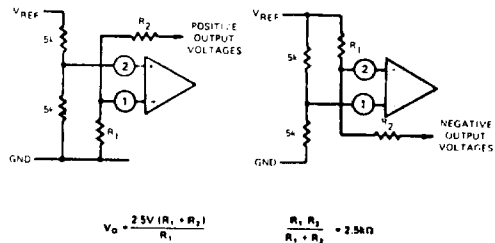


Figure 6. Error Amplifier Biasing Circuits. (Note: Change in Input Connections for Opposite Polarity Outputs)

age to get 25% duty cycle with the error amplifier signaling maximum duty cycle.

In addition to constant current limiting, pins 4 and 5 may also be used in transformer-coupled circuits to sense primary current and shorten an output pulse, should transformer saturation occur. (Refer to Figure 15.) Another application is to ground pin 5 and use pin 4 as an additional shutdown terminal, i.e., the output will be off with pin 4 open and on when it is grounded. Finally, foldback current limiting can be provided with the network of Figure 8. This circuit can reduce the short-

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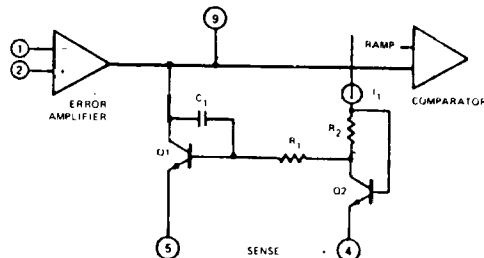


Figure 7. Current Limiting Circuitry of the XR-1524

circuit current (I_{SC}) to approximately one-third the maximum available output current (I_{MAX}).

The shutdown Pin (Pin 10) should be grounded whenever the shutdown circuitry is not used. If the shutdown function is used, Pin 10 should be driven from a low impedance source to prevent noise pickup.

OUTPUT CIRCUITS

The outputs of the XR-1524 are two identical NPN transistors with both collectors and emitters uncommitted. Each output transistor has antisaturation circuitry for fast response, and current limiting set for a maximum output current of approximately 100 mA. The availability of both collectors and emitters allows maximum versatility to enable driving either NPN or PNP external transistors.

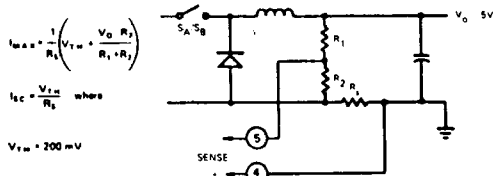


Figure 8. Foldback Current Limiting Can Be Used to Reduce Power Dissipation Under Shorted Output Conditions

In considering the application of the XR-1524 to voltage regulator circuitry, there are a multitude of output configurations possible. In general, however, they fall into three basic classifications:

1. Capacitor-diode coupled voltage multipliers
2. Inductor-capacitor single-ended circuits
3. Transformer-coupled circuits

Examples of each category are shown in Figures 9, 10 and 11. In each case, the switches indicated can be either the output transistors in the XR-1524 or added external transistors according to the load current requirements.

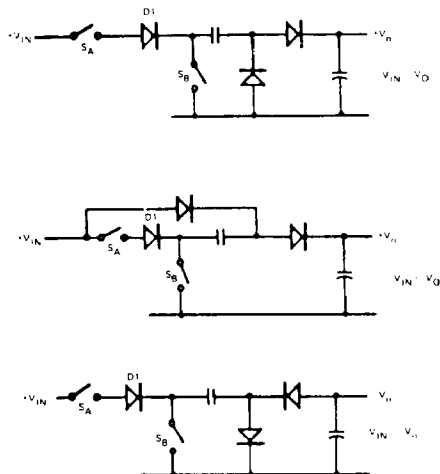


Figure 9. Capacitor-Diode Coupled Voltage Multiplier Output Stages. (Note: Diode D1 is Necessary to Prevent Reverse Emitter-Base Breakdown of Transistor Switch S_A)

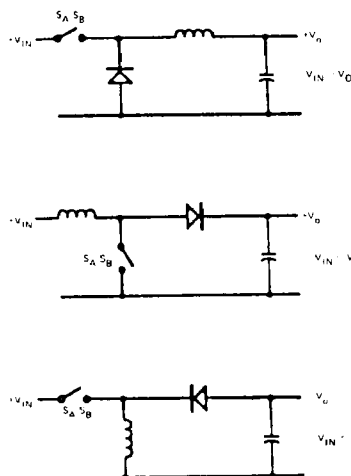


Figure 10. Single-ended Inductor Circuits Where the Two Outputs of the XR-1524 are Connected in Parallel

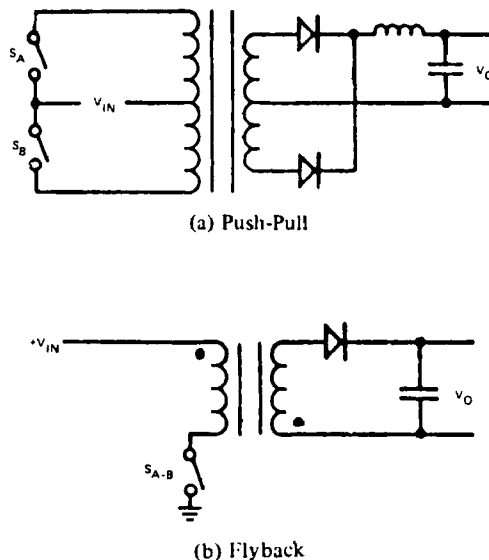


Figure 11. Push-Pull and Flyback Connections for Transformer-Coupled Outputs

XR-15/25/3524

DEADBAND CONTROL

The XR-1524 pulse width modulating regulator provides two outputs which alternate in turning on for push-pull inverter applications. The internal oscillator sends a momentary blanking pulse to both outputs at the end of each period to provide a deadband so that there cannot be a condition when both outputs are on at the same time. The amount of deadband is determined by the width of the blanking pulse appearing on pin 3 and can be controlled by any one of the four techniques described below:

Method 1: For 0.2 to 2.0 microseconds, the deadband is controlled by the timing capacitor, C_T , on pin 7. The relationship between C_T and deadband is shown in Figure 4. Of course, since C_T also helps determine the operating frequency, the range of control is somewhat limited.

Method 2: For 0.5 to 5.0 microseconds, the blanking pulse may be extended by adding a small capacitor from pin 3 to ground. The value of the capacitor must be less than 1000 pF or triggering will become unreliable.

Method 3: For longer and more well-controlled blanking pulses, a simple one-shot latch similar to the circuit shown in Figure 12 should be used.

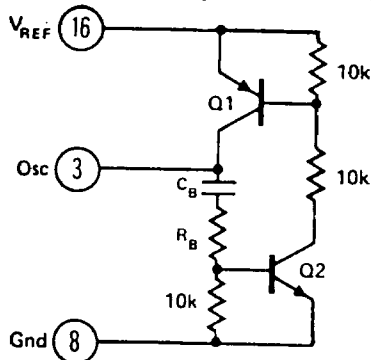


Figure 12. Recommended External Circuitry for Long Duration Blanking Pulse Generation (Method 3 of Deadband Control. Note: For 5 μ sec blanking, choose $C_B = 200$ pF, $R_B = 10$ K Ω)

When this circuit is triggered by the oscillator output pulse, it will latch for a period determined by $C_B R_B$ providing a well-defined deadband.

Another use for this circuit is as a buffer when several other circuits are to be synchronized to one master oscillator. This one-shot latch will provide an adequate signal to insure that all the slave circuits are completely reset before allowing the next timing period to begin.

Note that with this circuit, the blanking pulse holds off the oscillator so its width must be subtracted from the overall period when selecting R_T and C_T .

Method 4: Another way of providing greater deadband is just to limit the maximum pulse width. This can be done by using a clamp to limit the output voltage from the error amplifier. A simple way of achieving this clamp is with the circuit shown in Figure 13.

This circuit will limit the error amplifier's voltage range since its current source output will only supply 200 μ A. Additionally, this circuit will not affect the operating frequency.

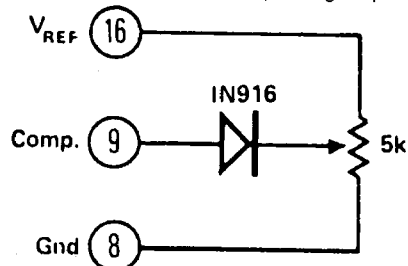


Figure 13. Using a Clamp Diode to Control Deadband (Method 4 of Deadband Control)

APPLICATIONS INFORMATION

POLARITY CONVERTING REGULATOR

The XR-1524 pulse width modulating regulator can be interconnected as shown in Figure 14. The component values shown in the figure are chosen to generate a -5 volt regulated supply voltage from a +15 volt input. This circuit is useful for an output current of up to 20 mA with no additional boost transistors required. Since the output transistors are current limited, no additional protection is necessary. Also, the lack of an inductor allows the circuit to be stabilized with only the output capacitor.

FLYBACK CONVERTER

Figure 15 shows the application of XR-1524 in a low-current DC-DC converter, using the flyback converter principle (see Figure 11b). The particular values given in the figure are chosen to generate ± 15 volts at 20 mA from a +5 volt regulated line. The reference generator in the XR-1524 is unused. The reference is provided by the input voltage. Current limiting in a flyback converter is difficult and is accomplished here by sensing current in the primary line and resetting a soft-start circuit.

XR-15/25/3524

SINGLE ENDED REGULATOR

The XR-1524 operates as an efficient single-ended pulse width modulating regulator, using the circuit connection shown in Figure 16. In this configuration, the two output transistors of the circuit are connected in parallel by shorting pins (12, 13) and (11, 14) together, respectively, to provide for effective 0 - 90% duty-cycle modulation. The use of an output inductance requires an R-C phase compensation on pin 9, as shown in the figure.

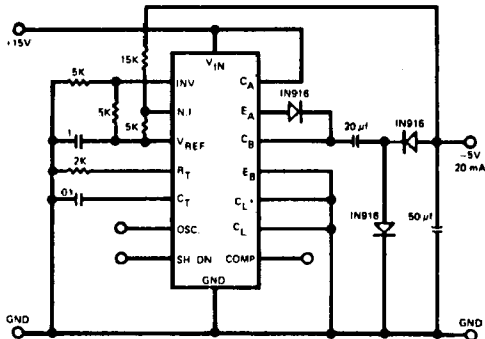


Figure 14. Circuit Connection for Polarity Converting Regulator ($V_{in} = +15V$, $V_{out} = -5V$)

PUSH-PULL CONVERTER

The circuit of Figure 17 shows the use of XR-1524 in a transformer-coupled DC-DC converter with push-pull outputs (see Figure 11a). Note that the oscillator must be set at twice the desired output frequency as the XR-1524's internal flip-flop divides the frequency by 2 as it switches the P.W.M. signal from one output to the other. Current limiting is done in the primary. This causes the pulse/width to be reduced automatically if the transformer saturation occurs.

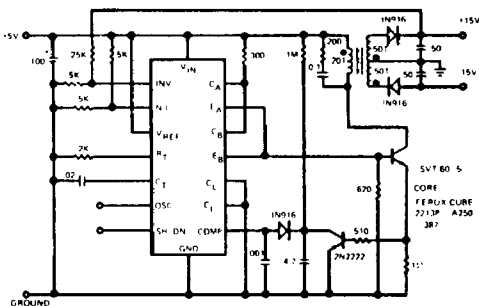


Figure 15. A Low-Current DC-DC Converter Using Flyback Principle ($V_{out} = \pm 15V$, $V_{in} = +5V$, $I_L \leq 20$ mA)

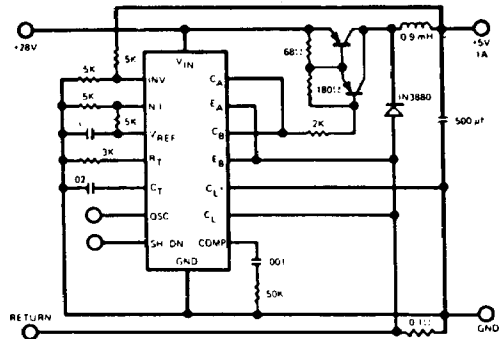


Figure 16. Conventional Single-Ended Regulator Connection ($V_{in} = +28V$, $V_o = +5V$, $I_{out} \leq 1$ Amp)

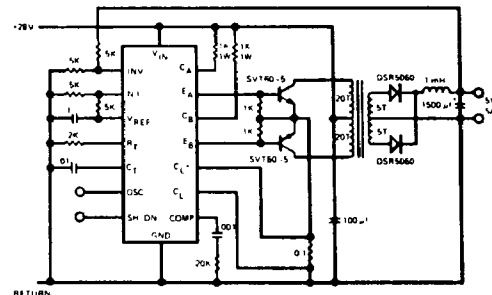


Figure 17. A High-Current DC-DC Converter with Push-Pull Outputs ($V_{in} = +28V$, $V_o = +5V$, $I_o \leq 5A$)

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XR-1488/1489A

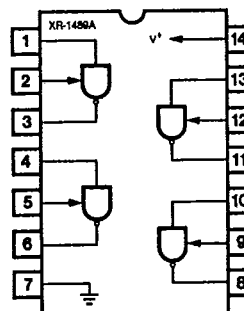
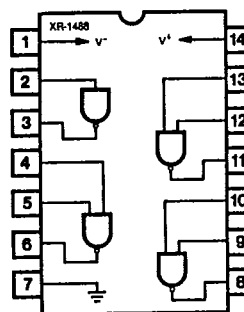
Quad Line Driver/Receiver

GENERAL DESCRIPTION

The XR-1488 is a monolithic quad line driver designed to interface data terminal equipment with data communications equipment in conformance with the specifications of EIA Standard No. RS232C. This extremely versatile integrated circuit can be used to perform a wide range of applications. Features such as output current limiting, independent positive and negative power supply driving elements, and compatibility with all DTL and TTL logic families greatly enhance the versatility of the circuit.

The XR-1489A is a monolithic quad line receiver designed to interface data terminal equipment with data communications equipment. The XR-1489A quad receiver along with its companion circuit, the XR-1488 quad driver, provide a complete interface system between DTL or TTL logic levels and the RS232C defined voltage and impedance levels.

FUNCTIONAL BLOCK DIAGRAMS



ABSOLUTE MAXIMUM RATINGS

Power Supply	
XR-1488	± 15 Vdc
XR-1489A	+ 10 Vdc
Power Dissipation	
Ceramic Package	1000 mW
Derate above +25°C	6.7 mW/°C
Plastic Package	650 mW/°C
Derate above +25°C	5 mW/°C

ORDERING INFORMATION

Part Number	Package	Operating Temperature
XR-1488N	Ceramic	0°C to +70°C
XR-1488P	Plastic	0°C to +70°C
XR-1489AN	Ceramic	0°C to +70°C
XR-1489AP	Plastic	0°C to +70°C

SYSTEM DESCRIPTION

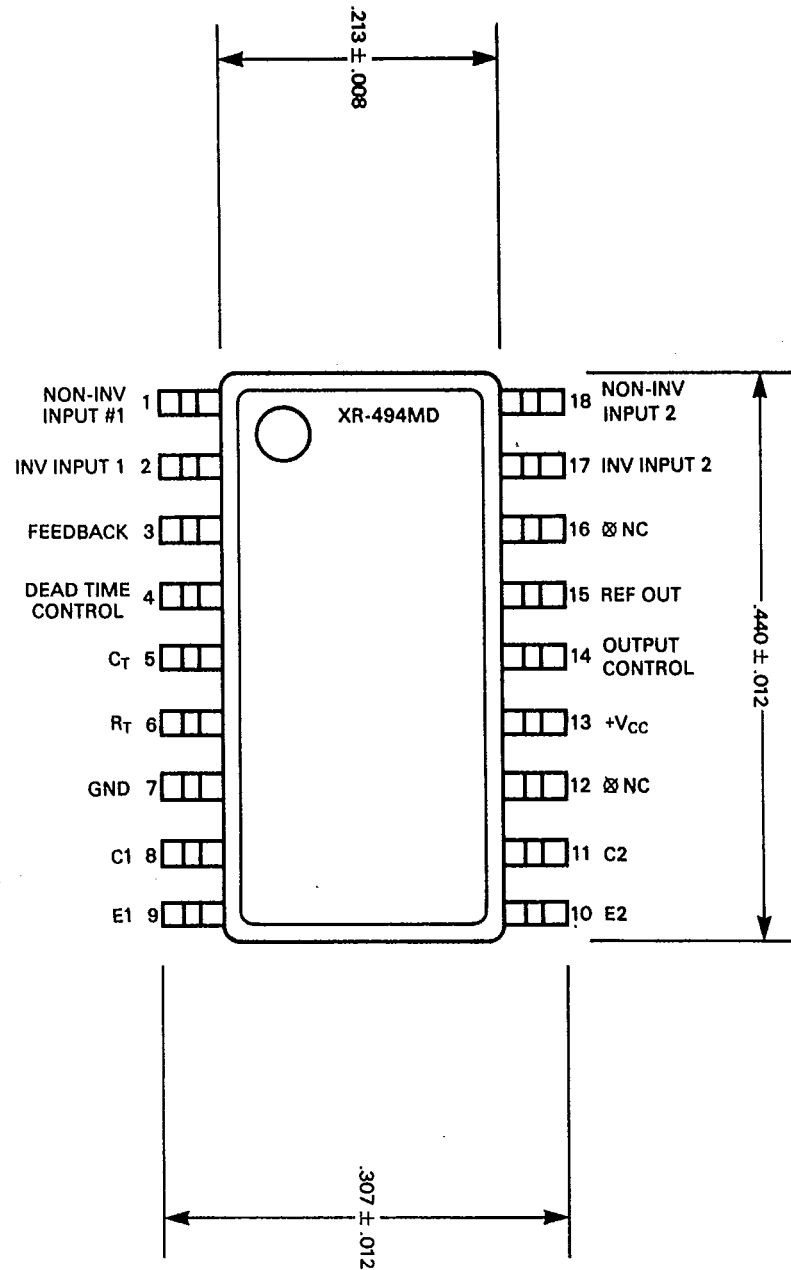
The XR-1488 and XR-1489A are a matched set of quad line drivers and line receivers designed for interfacing between TTL/DTL and RS232C data communication lines.

The XR-1488 contains four independent split supply line drivers, each with a ± 10 mA current limited output. For RS232C applications, the slew rate can be reduced to the 30 V/ μ S limit by shunting the output to ground with a 410 pF capacitor. The XR-1489A contains four independent line receivers, designed for interfacing RS232C to TTL/DTL. Each receiver features independently programmable switching thresholds with hysteresis, and input protection to ± 30 V. The output can typically source 3 mA and sink 20 mA.

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Dual-Polarity Tracking Voltage Regulator

GENERAL DESCRIPTION

The XR-1468/1568 is a dual polarity tracking voltage regulator, internally trimmed for symmetrical positive and negative 15V outputs. Current output capability is 100 mA, and may be increased by adding external pass transistors. The device is intended for local "on-card" regulation, which eliminates the distribution problems associated with single point regulation.

The XR-1468CN and XR-1568N are guaranteed over the 0°C to 70°C commercial temperature range. The XR-1568M is rated over the full military temperature range of -55°C to +125°C.

FEATURES

Internally Set for $\pm 15V$ Outputs
 ± 100 mA Peak Output Current
 Output Voltages Balanced Within 1% (XR-1568)
 0.06% Line and Load Regulation
 Low Stand-By Current
 Output Externally Adjustable from ± 8 to ± 20 Volts
 Externally Adjustable Current Limiting
 Remote Sensing

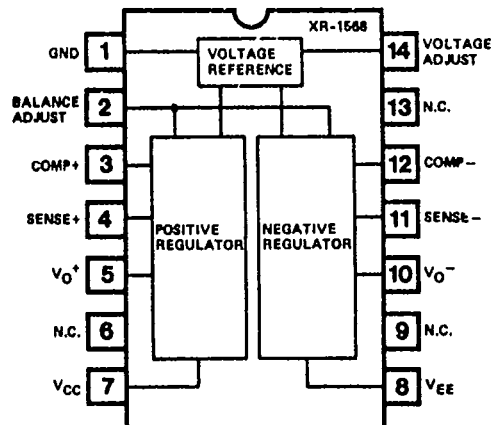
APPLICATIONS

Main Regulation in Small Instruments
 On-Card Regulation in Analog and Digital Systems
 Point-of-Load Precision Regulation

ABSOLUTE MAXIMUM RATINGS

Power Supply	± 30 Volts
Minimum Short-Circuit Resistance	4.0 Ohms
Load Current, Peak	± 100 mA
Power Dissipation	
Ceramic (N) Package	1.0 Watt
Derate Above +25°C	6.7 mW/°C
Operating Temperature	
XR-1568M	-55°C to +125°C
XR-1568/XR-1468C	0°C to +70°C
Storage Temperature	-65°C to +150°C

FUNCTIONAL BLOCK DIAGRAM



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ORDERING INFORMATION

Part Number	Temperature	Output Offset	Package
XR-1568M	-55°C to +125°C	± 150 mV max	Ceramic
XR-1568N	0°C to +70°C	± 150 mV max	Ceramic
XR-1468CN	0°C to +70°C	± 300 mV max	Ceramic

SYSTEM DESCRIPTION

The XR-1468/1568 is a dual polarity tracking voltage regulator combining two separate regulators with a common reference element in a single monolithic circuit, thus providing a very close balance between the positive and negative output voltages. Outputs are internally set to ± 15 Volts but can be externally adjusted between ± 8.0 to ± 20 Volts with a single control. The circuit features ± 100 mA output current, with externally adjustable current limiting, and provision for remote voltage sensing.