# Pulse-Width Modulating Regulators

## GENERAL DESCRIPTION

The XR-1525A/1527A is a series of monolithic intergrated circuits that contain all of the control circuitry necessary for a pulse-width modulating regulator. Included in the 16-Pin dual-in-line package is a voltage reference, an error amplifier, a pulse-width modulator, an oscillator, under-voltage lockout, soft-start circuitry, and output drivers.

The XR-1525A/2525A/3525A series features NOR logic, giving a LOW output for an OFF state. The XR-1527A/2527A/3527A series features OR logic, giving a HIGH output for an OFF state.

## FEATURES

8V to 35V Operation
5.1V Reference Trimmed to ± 1%
100 Hz to 500 kHz Oscillator Range
Separate Oscillator Sync Terminal
Adjustable Deadtime Control
Internal Soft-Start
Input Under-voltage Lockout
Latching PWM to Prevent Double Pulsing
Dual Source/Sink Output Drivers
  Capable of Over 200 mA
Power-FET Drive Capability

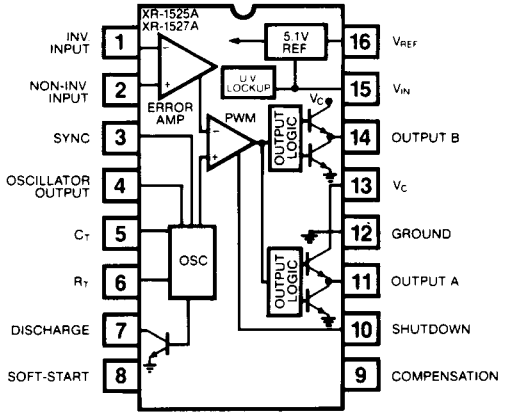
## APPLICATIONS

Power Control Systems
Switching Regulators
Industrial Controls

## ABSOLUTE MAXIMUM RATINGS

| | |
|---|---|
| Supply Voltage (+ $V_{IN}$) | + 40V |
| Collector Supply Voltage ($V_C$) | + 40V |
| Logic Inputs | -0.3V to 5.5V |
| Analog Inputs | -0.3V to + $V_{IN}$ |
| Output Current, Source or Sink | 500 mA |
| Reference Output Current | 50 mA |
| Oscillator Charging Current | 5 mA |
| Power Dissipation | |
| Ceramic Package | 1000 mW |
| Derate above $T_A$ = +25°C | 8.0 mW/°C |
| Plastic Package | 625 mW |
| Derate above $T_A$ = +25°C | 5.0 mW/°C |
| Operating Junction Temperature ($T_J$) | + 150°C |
| Storage Temperature Range | -65°C to +150°C |

## FUNCTIONAL BLOCK DIAGRAM




## ORDERING INFORMATION

| Part Number | Package | Operating Temperature |
|---|---|---|
| XR-1525A/27AN | Ceramic | -55°C to +125°C |
| XR-2525A/27AN | Ceramic | -25°C to +85°C |
| XR-2525A/27AP | Plastic | -25°C to +85°C |
| XR-3525A/27AN | Ceramic | 0°C to +70°C |
| XR-3525A/27AP | Plastic | 0°C to +70°C |

## SYSTEM DESCRIPTION

The on-chip 5.1-volt reference is trimmed to ± 1% initial accuracy, and the common-mode input range of the error amplifier is extended to include the reference voltage. Deadtime is adjustable with a single external resistor. A sync input to the oscillator allows multiple units to be slaved together, or a single unit to be synchronized to an external clock. A positive-going signal applied to the shut-down pin provides instantaneous turnoff of the outputs. The under-voltage lockout circuitry keeps the output drivers off, and the soft-start capacitor discharged, for an input voltage below the required value. The latch on the PWM comparator insures the outputs to be active only once per oscillator period, thereby eliminating any double pulse-ing. The latch is reset with each clock pulse.

The output drivers are totem-pole designs capable of sink-ing and sourcing over 200 mA.

## ELECTRICAL CHARACTERISTICS

**Test Conditions:** $V_{IN}$ = +20V, $T_J$ = Full operating temperature range, unless otherwise specified.

| PARAMETERS | XR-1525A/2525A XR-1527A/2527A | | | XR-3525A XR-3527A | | | UNIT | CONDITIONS |
|---|---|---|---|---|---|---|---|---|
| | MIN | TYP | MAX | MIN | TYP | MAX | | |
| **VOLTAGE REFERENCE SECTION** | | | | | | | | |
| Output Voltage | 5.05 | 5.10 | 5.15 | 5.00 | 5.10 | 5.20 | V | $T_J$ = 25°C |
| Line Regulation | | 10 | 20 | | 10 | 20 | mV | $V_{IN}$ = 8V to 35V |
| Load Regulation | | 20 | 50 | | 20 | 50 | mV | $I_L$ = 0 to 20 mA |
| Temperature Stability (2) | | 20 | 50 | | 20 | 50 | mV | $T_J$ = Full Operating Range |
| Total Output Variation (2) | 5.00 | | 5.20 | 4.95 | | 5.25 | V | Line, Load and Temperature |
| Output Short Circuit Current | | 80 | 100 | | 80 | 100 | mA | $T_J$ = 25°C, $V_{ref}$ = 0V |
| Output Noise Voltage (2) | | 40 | 200 | | 40 | 200 | μV rms | $T_J$ = 25°C, 10 Hz ≤ f ≤ 10 kHz |
| Long Term Stability (2) | | 20 | 50 | | 20 | 50 | mV/kHR | $T_J$ = 125°C |
| **OSCILLATOR SECTION (Note 3)** | | | | | | | | |
| Initial Accuracy (2,3) | | ±2 | ±6 | | ±2 | ±6 | % | $T_J$ = 25°C, f = 40 kHz |
| Temperature Stability (2) | | ±3 | ±6 | | ±3 | ±6 | % | $T_J$ = Full Operating Range |
| Input Voltage Stability (2,3) | | ±0.3 | ±1 | | ±1 | ±2 | % | $V_{IN}$ = 8V to 35V |
| Minimum Frequency | | | 100 | | | 100 | Hz | $R_T$ = 150 kΩ, $C_T$ = 0.1 μF |
| Maximum Frequency | 400 | | | 400 | | | kHz | $R_T$ = 2 kΩ, $C_T$ = 1 nF |
| Current Mirror | 1.7 | 2.0 | 2.2 | 1.7 | 2.0 | 2.2 | mA | $I_{RT}$ = 2 mA |
| Clock Amplitude (2,3) | 3.0 | 3.5 | | 3.0 | 3.5 | | V | |
| Clock Pulse Width (2,3) | 0.3 | 0.5 | 1.0 | 0.3 | 0.5 | 1.0 | μsec | $T_J$ = 25°C, $R_D$ = 0Ω |
| Sync Threshold | 1.2 | 2.0 | 2.8 | 1.2 | 2.0 | 2.8 | V | |
| Sync Input Current | | 1.0 | 2.5 | | 1.0 | 2.5 | mA | Sync Voltage = 3.5V |
| **ERROR AMPLIFIER SECTION ($V_{CM}$ = 5.1V)** | | | | | | | | |
| Input Offset Voltage | | 0.5 | 5.0 | | 2 | 10 | mV | |
| Input Bias Current | | 1 | 10 | | 1 | 10 | μA | |
| Input Offset Current | | | 1 | | | 1 | μA | |
| DC Open-Loop Gain | 60 | 75 | | 60 | 75 | | dB | $R_L$ ≥ 10 MΩ |
| Gain Bandwidth Product (2) | 1 | 2 | | 1 | 2 | | MHz | $T_J$ = 25°C |
| Output Low Voltage | | 0.2 | 0.5 | | 0.2 | 0.5 | V | |
| Output High Voltage | 3.8 | 5.6 | | 3.8 | 5.6 | | V | |
| Common-Mode Rejection Ratio | 60 | 75 | | 60 | 75 | | dB | $V_{CM}$ = 1.5V to 5.2V |
| Supply Voltage Rejection Ratio | 50 | 60 | | 50 | 60 | | dB | $V_{IN}$ = 8V to 35V |
| **PULSE-WIDTH MODULATING COMPARATOR** | | | | | | | | |
| Minimum Duty Cycle | | | 0 | | | 0 | % | |
| Maximum Duty Cycle | 45 | 49 | | 45 | 49 | | % | |
| Input Threshold (3) | 0.6 | 0.9 | | 0.6 | 0.9 | | V | Zero Duty Cycle |
| Input Threshold (3) | | 3.3 | 3.6 | | 3.3 | 3.6 | V | Maximum Duty Cycle |
| Input Bias Current (2) | | 0.05 | 1.0 | | 0.05 | 1.0 | μA | |
| **SOFT-START SECTION** | | | | | | | | |
| Soft-Start Current | 25 | 50 | 80 | 25 | 50 | 80 | μA | $V_{shutdown}$ = 0V |
| Soft-Start Voltage | | 0.4 | 0.6 | | 0.4 | 0.6 | V | $V_{shutdown}$ = 2V |
| Shutdown Input Current | | 0.4 | 1.0 | | 0.4 | 1.0 | mA | $V_{shutdown}$ = 2.5V |
| **OUTPUT DRIVERS (Each Output) $V_C$ = 20V** | | | | | | | | |
| Output Low Voltage | | 0.2 | 0.4 | | 0.2 | 0.4 | V | $I_{sink}$ = 20 mA |
| Output Low Voltage | | 1.0 | 2.0 | | 1.0 | 2.0 | V | $I_{sink}$ = 100 mA |
| Output High Voltage | 18 | 19 | | 18 | 19 | | V | $I_{source}$ = 20 mA |
| Output High Voltage | 17 | 18 | | 17 | 18 | | V | $I_{source}$ = 100 mA |
| Under-voltage Lockout | 6 | 7 | 8 | 6 | 7 | 8 | V | $V_{comp}$ and $V_{SS}$ = High |
| Collector Leakage (4) | | | 200 | | | 200 | μA | $V_C$ = 35V |
| Rise Time (2) | | 100 | 600 | | 100 | 600 | nsec | $T_J$ = 25°C, $C_L$ = 1 nF |
| Fall Time (2) | | 50 | 300 | | 50 | 300 | nsec | $T_J$ = 25°C, $C_L$ = 1 nF |
| Shutdown Delay (2) | | 0.2 | 0.5 | | 0.2 | 0.5 | μsec | $V_{SD}$ = 3V, $C_S$ = 0, $T_J$ = 25°C |
| **TOTAL STANDBY CURRENT** | | | | | | | | |
| Supply Current | | 14 | 20 | | 14 | 20 | mA | $V_{IN}$ = 35V |

Note 2: These parameters, although guaranteed over the recommended operating conditions, are not 100% tested in production.
Note 3: Tested at f = 40 kHz ($R_T$ = 3.6 kΩ, $C_T$ = 0.01 μF, $R_D$ = 0Ω).
Note 4: Applies to XR-1525A/2525A/3525A only, due to polarity of output pulses.

## PRINCIPLES OF OPERATION

The different control blocks within the XR-1525A/1527A function as follows:

### Voltage Reference Section

The internal voltage reference circuit of the XR-1525A/1527A is based on the well-known "band-gap" reference, with a nominal output voltage of 5.1 volts, internally trimmed to ±1% accuracy. It is short circuit protected and is capable of providing up to 20 mA of reference current. A simplified circuit schematic is shown in Figure 7.

### Oscillator Section

The sawtooth oscillator derives its frequency from an external timing resistor/capacitor pair. The timing resistor, $R_T$, determines the charging current into the timing capacitor, $C_T$. The magnitude of this current is approximately given by:

$$\frac{V_{ref} - 2V_{BE}}{R_T} \approx \frac{3.7V}{R_T}$$

where $R_T$ may range from 2 kΩ to 150 kΩ. In general, temperature stability is maximized with lower values of $R_T$. The current source charging $C_T$ creates a linear ramp voltage which is compared to fixed thresholds within. When the capacitor voltage reaches +3.3 volts, the oscillator output (Pin 4) goes high, turning ON the discharge transistor. The capacitor is discharged through the deadtime resistor, $R_D$. When the voltage on $C_T$ falls to +1.0 volt, the oscillator output goes low, the discharge transistor is turned OFF, and the capacitor is charged through the constant current source as another cycle starts. With large values of $R_D$ (500Ω, maximum), deadtime is increased. The actual operating frequency is thus a function of the charge and discharge times. Figure 2 shows how charge time is related to $R_T$ and $C_T$, with $R_D$ = 0Ω. Deadtime is a function of $R_D$ and $C_T$, and can vary between 0.5 to 7 μsec, with $R_D$ = 0Ω, as shown in Figure 3. The equivalent circuit schematic of the oscillator section is shown in Figure 8.

A unit can be synchronized to an external source by selecting its free-running oscillator period to be 10% longer than the period of the external source. A positive-going pulse of at least 300 nsec wide should be applied to the sync terminal for reliable triggering; however, it should not exceed the free-running pulse width by more than 200 nsec. The amplifier of the pulse should be kept between 2 and 5 volts. Multiple units can be synchronized to each other by connecting all $C_T$ pins, and oscillator output pins together; $R_T$ pins and discharge pins on slave oscillators must be left open.

### Error Amplifier

The error amplifier of the XR-1525A/1527A is a differential input transconductance amplifier. Its common-mode range covers the reference voltage. Its open-loop gain, typically 75 dB, can be reduced by a load resistor on Pin 9. To ensure proper operation, the output load should be limited to 50 kΩ or greater. An equivalent circuit schematic of the error amplifier is shown in Figure 9.

### Soft-Start Circuitry

**The soft-start function is provided to achieve controlled turn-on of the pulse-width modulator. When power is applied to the device, the external capacitor, $C_{soft\text{-}start}$, on Pin 8 is charged by a 50 μA constant current source. The ramp voltage appearing on this capacitor is fed into the pulse-width modulator, which gradually increases its output duty cycle from zero to the prescribed value. When the shutdown terminal is raised to a positive value, an internal transistor turns ON, and discharges the capacitor, $C_S$, causing the PWM to turn OFF. When the shutdown terminal is open or pulled low, the transistor turns OFF, and $C_S$ begins charging as before. However, whenever the shutdown circuitry is not used, Pin 10 should be grounded. If the shutdown function is used, Pin 10 should be driven from a low impedance source to prevent noise pickup. The turn-on time (time required to charge $C_S$ to +2.7 volts) can be approximated as:**

$$T_C \text{ (msec)} = 54\ C_S$$

where $C_S$ is in μF.

### Output Section

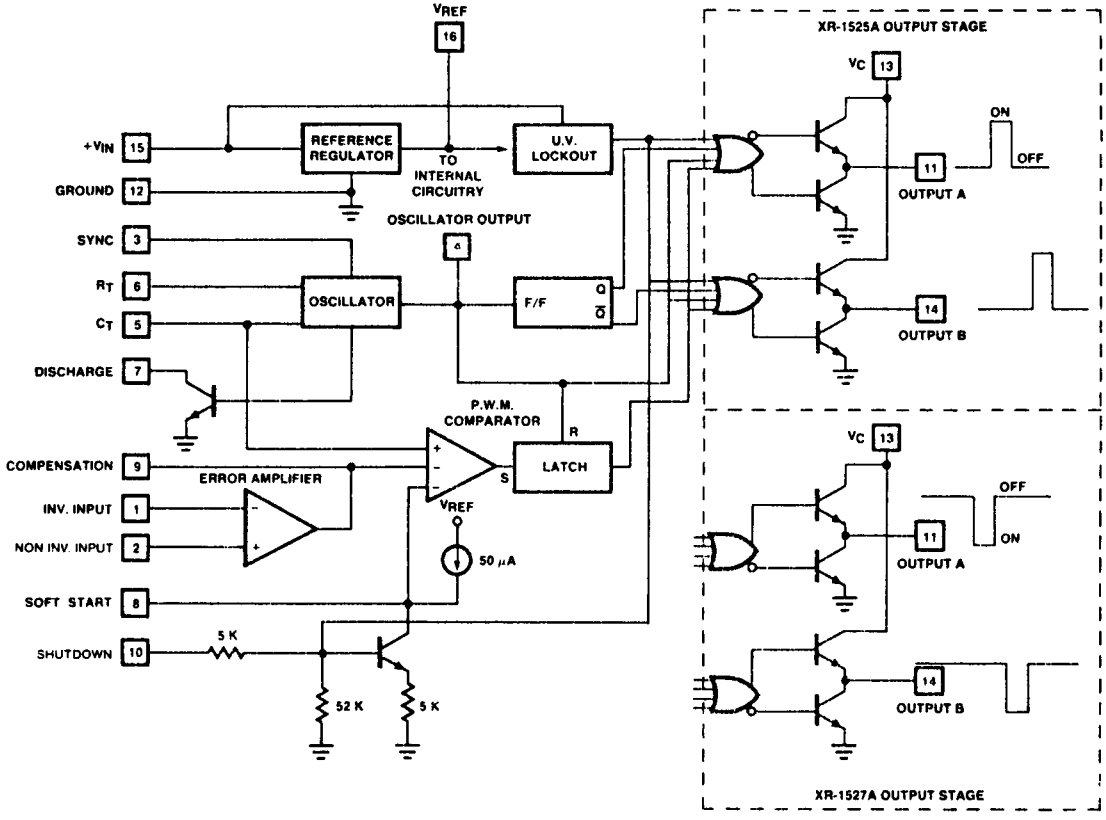
The output drivers of the XR-1525A/1527A are totem-pole designs capable of sinking and sourcing 200 mA. The low source impedance in the high or low states provides ideal interfacing with bipolar as well as FET power transistors. Either push-pull or single-ended output configurations are possible with separate collector supply terminals. The equivalent schematic of the output drivers is shown in Figure 10.

## RECOMMENDED OPERATING CONDITIONS

Note 1: Range over which the device is functional and parameter limits are guaranteed.

| | |
|---|---|
| Collector Supply Voltage ($V_C$) | +4.5V to +35V |
| Sink/Source Load Current (Steady State) | 0 to 100 mA |
| Sink/Source Load Current (Peak) | 0 to 400 mA |
| Reference Load Current | 0 to 20 mA |
| Oscillator Frequency Range | 100 Hz to 400 kHz |
| Oscillator Timing Resistor | 2 kΩ to 150 kΩ |
| Oscillator Timing Capacitor | 0.001 μF to 0.1 μF |
| Deadtime Resistor Range | 0 to 500Ω |

## EQUIVALENT SCHEMATIC DIAGRAM



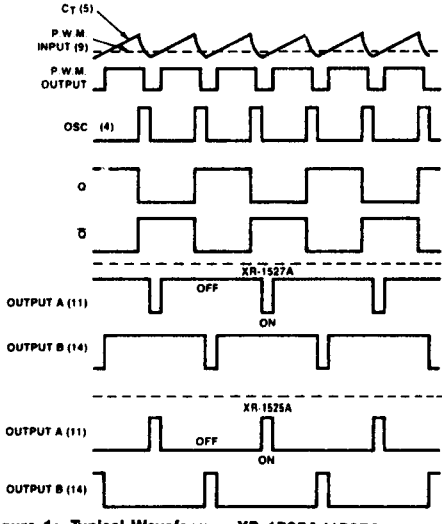




**Figure 1: Typical Waveforms—XR-1525A/1527A**

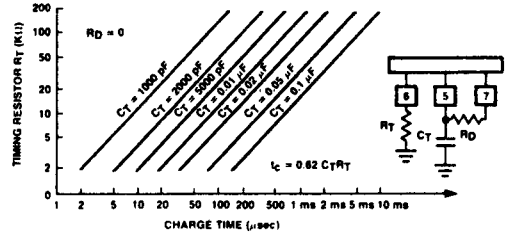



**Figure 2. Oscillator Charge Time vs $R_T$ and $C_T$**

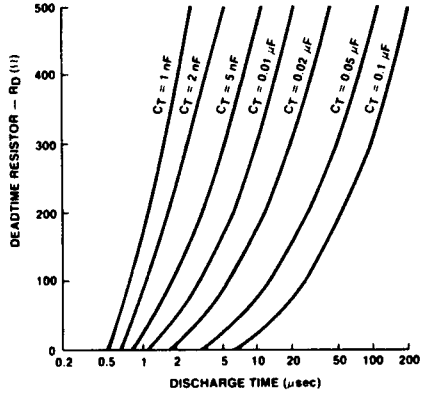



Figure 3. Oscillator Discharge Time vs $R_D$ and $C_T$

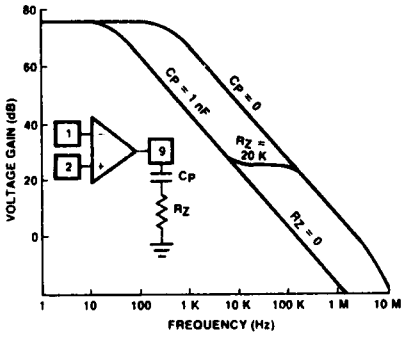



Figure 4. Error Amplifier Open-Loop Frequency Response.

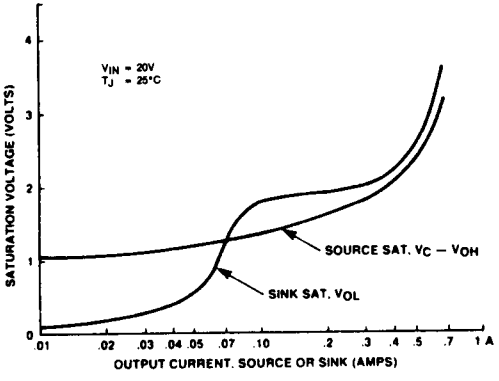



Figure 5. Output Saturation Characteristics

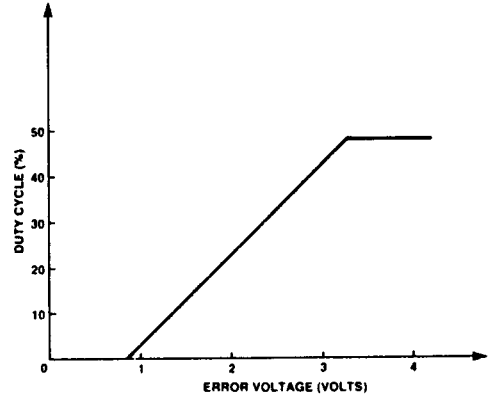



Figure 6. Output Duty Cycle vs Error Voltage

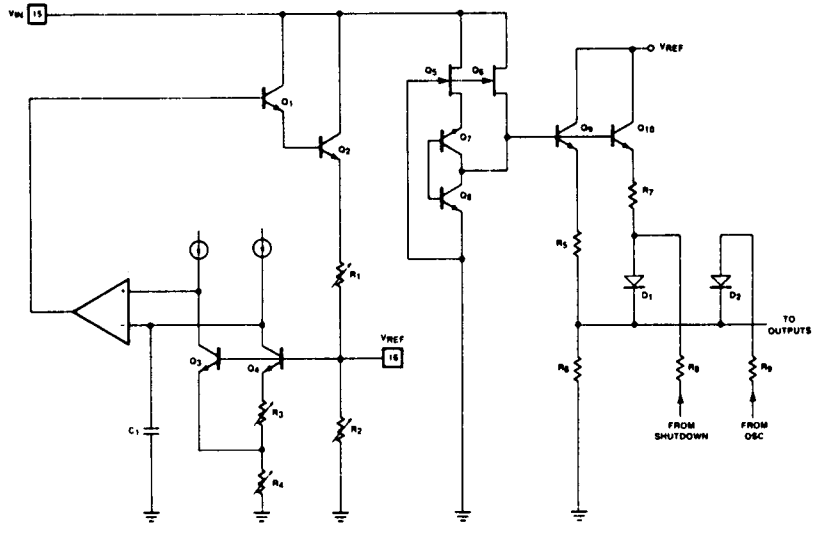



Figure 7. Equivalent Schematic of Voltage Reference Section

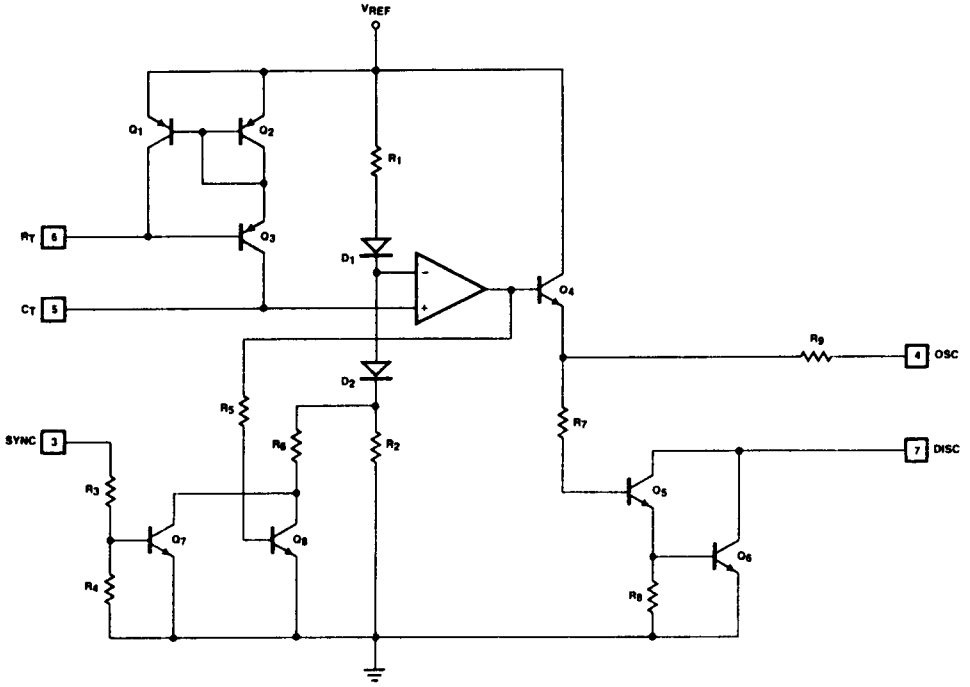



**Figure 8. Equivalent Schematic of the Oscillator Section**

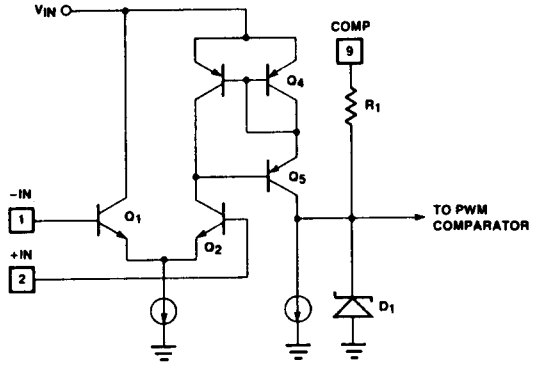



**Figure 9. Equivalent Schematic of Error Amplifier Section**

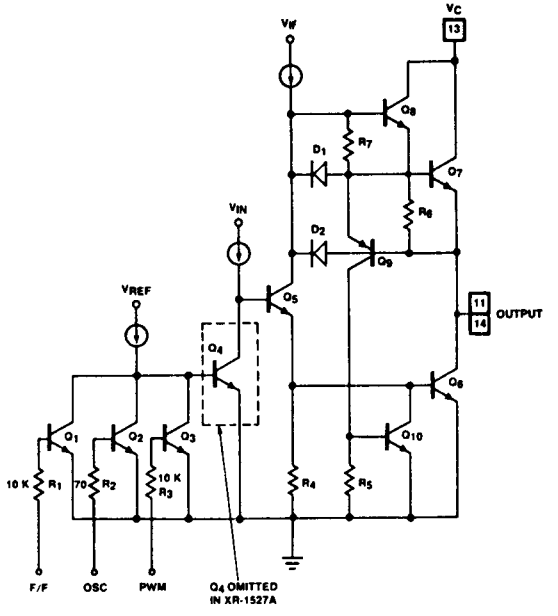



**Figure 10. Equivalent Schematic of Output Drivers**

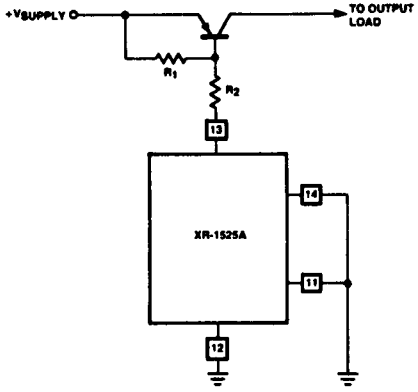



Figure 11. Single-Ended Output for XR-1525A

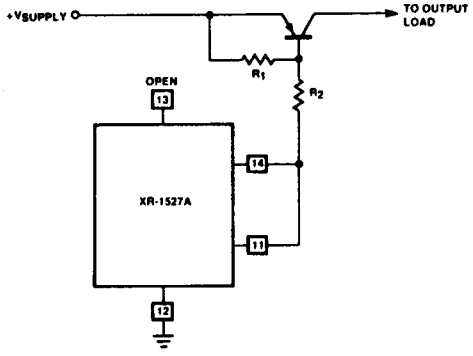



Figure 12. Single-Ended Output for XR-1527A

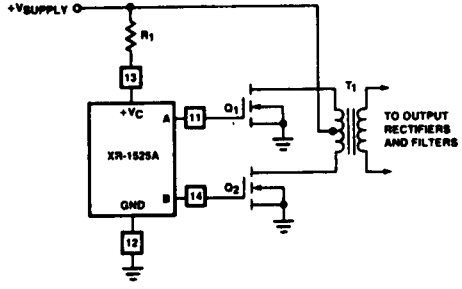



Figure 13. Push-Pull Outputs with XR-1525A

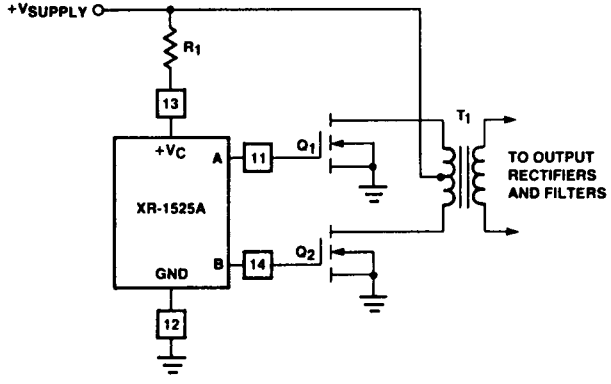



Figure 14. Power FET Push-Pull Outputs with XR-1525A

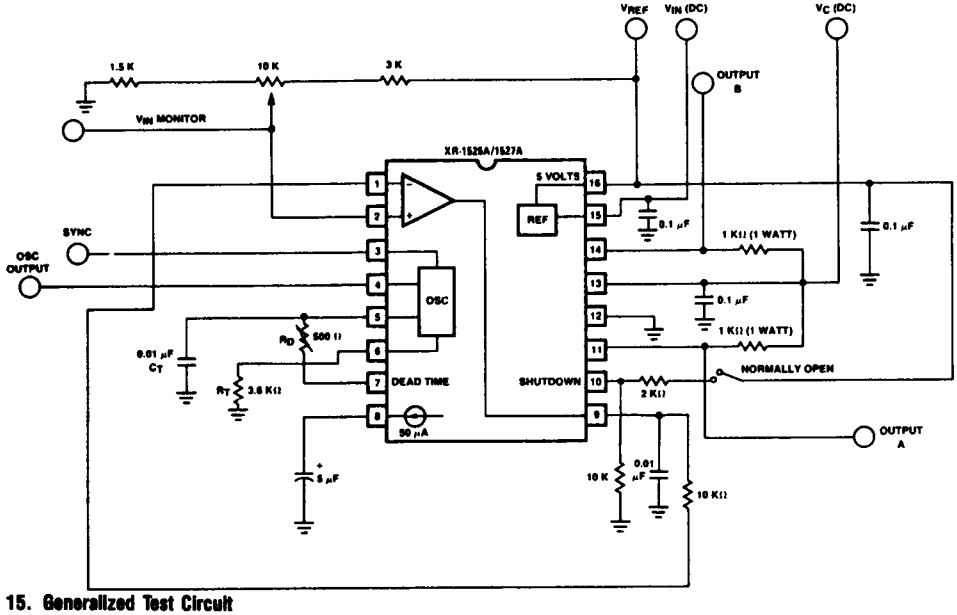



Figure 15. Generalized Test Circuit

EXAR

# 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.

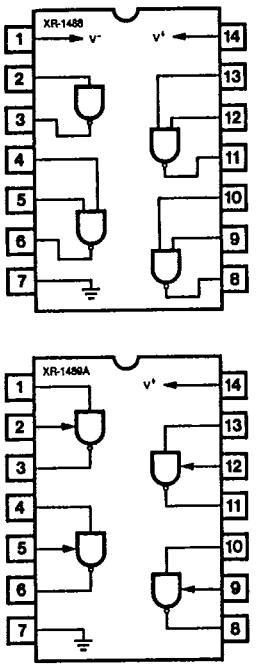
### ABSOLUTE MAXIMUM RATINGS

| | |
|---|---|
| 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 |

### FUNCTIONAL BLOCK DIAGRAMS



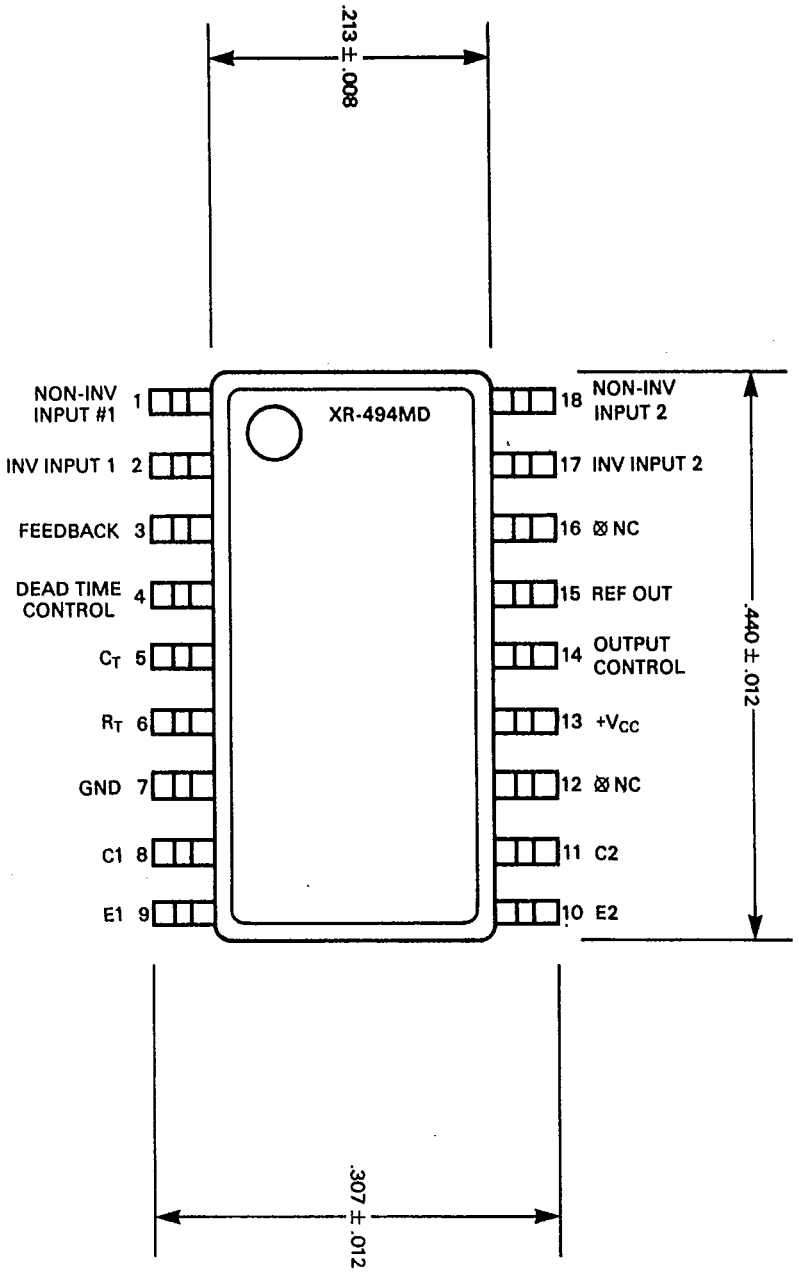

### SYSTEM DESCRIPTION

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/μS 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.

# XR-494

T-58-11-31



EXAR

# XR-1468/1568

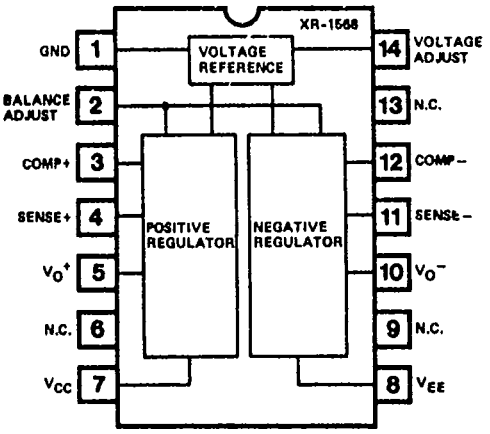
# Dual-Polarity Tracking Voltage Regulator

## 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.

## FUNCTIONAL BLOCK DIAGRAM




## FEATURES

Internally Set for ±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

## 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 |

## 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 |

## 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.