Absolute Maximum Ratings

(All voltages referenced to GND, unless otherwise noted.)

Supply Voltage V_{CC}..-0.3V to +6V
ST1, ST2, CK_RS, MODE (Note 1)................-0.3V to V_{CC} + 0.3V
ST1, ST2 Maximum Continuous Current (T_A < +125°C) ....±0.6A
ST1, ST2 Maximum Continuous Current (T_A < +100°C) ....±0.9A
ST1, ST2 Maximum Continuous Current (T_A < +85°C) ......±1.0A

Continuous Power Dissipation (T_A = +70°C)
    8-Pin SO (derate 18.9mW/°C above +70°C).............1509mW
Operating Temperature Range ....-40°C to +125°C
Storage Temperature Range ....-65°C to +150°C
Junction Temperature ....+150°C
Lead Temperature (soldering, 10s) ....+300°C
Soldering Temperature (reflow) ....+260°C

Note 1: ST1 and ST2 are not protected against short circuits. Damage to the device may result from a short-circuit fault.

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Package Thermal Characteristics (Note 2)

SO-EP
    Junction-to-Ambient Thermal Resistance (θ_{JA})...............53°C/W
    Junction-to-Case Thermal Resistance (θ_{JC}).....................5°C/W

Note 2: Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to **www.maximintegrated.com/thermal-tutorial**.

DC Electrical Characteristics

(V_{CC} = +3.0V to +5.5V, T_A = T_{MIN} to T_{MAX}. Typical values are at V_{CC} = +5.0V and T_A = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Voltage	V_{CC}		3.0		5.5	V
Supply Current	I_{CC}	MODE = V_{CC}, CK_RS unconnected (Note 3)		1.06	3	mA
Disable Supply Current	I_{SD}	MODE = GND, CK_RS unconnected			50	µA
External Resistance Range	R_S		10			kΩ
Driver Total Resistance	R_{OHL}	V_{CC} = 4.5V (Note 4)		0.5	1.0	Ω
		V_{CC} = 3.0V (Note 4)		0.6	1.2	
Undervoltage Lockout Threshold	V_{UVLO}	V_{CC} rising	0.8	1.9	2.7	V
Undervoltage-Lockout-Threshold Hysteresis	V_{UVLO_HST}			110		mV
Logic-Low Level (MODE, CK_RS)	V_{IL}	V_{CC} = 4.5V			0.8	V
		V_{CC} = 3.0V			0.7	
Logic-High Level (MODE, CK_RS)	V_{IH}		2.0			V
Input Leakage Current (MODE)	I_{LK}				1	µA
Internal Pulldown Resistance on CK_RS	R_{S_INT}	MODE = GND		165		kΩ
Thermal Shutdown	T_{SHDN}			165		°C
Thermal Shutdown Hysteresis	T_{SHDN_HST}			10		°C

Timing Characteristics

(V_{CC} = +3.0V to +5.5V, T_A = T_{MIN} to T_{MAX}. Typical values are at V_{CC} = +5.0V and T_A = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Switching Frequency	f_{SW}	MODE = V_{CC}, R_S = 10.5kΩ	0.75	1	1.35	MHz
		MODE = V_{CC}, CK_RS unconnected	65	100	160	kHz
CK_RS Input Frequency	f_{IN}	MODE = GND	0.2		2	MHz
ST1 and ST2 Duty Cycle	Dtc	MODE = V_{CC}	49	50	51	%
Crossover Dead Time	t_{DEAD}	R_L = 100Ω		20		ns
Watchdog Timeout	t_{WDOG}	MODE = GND	20		55	µs

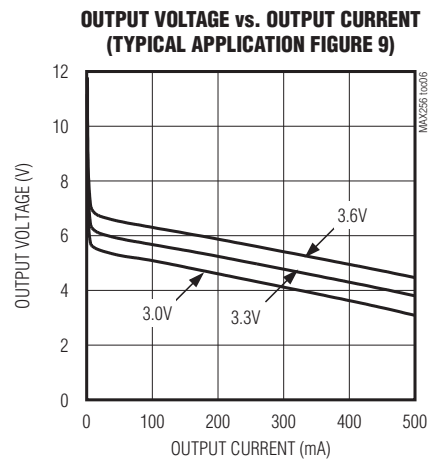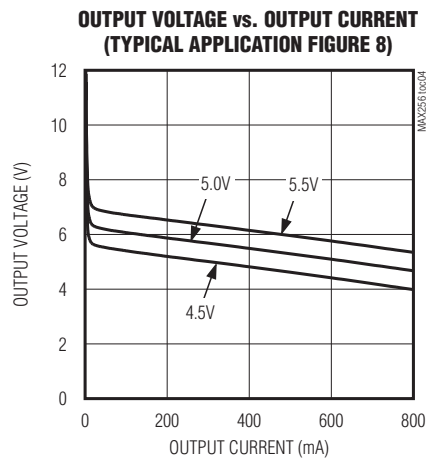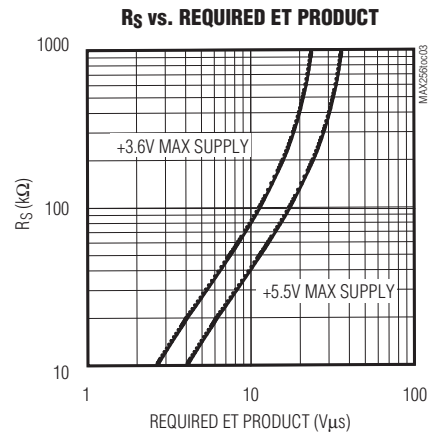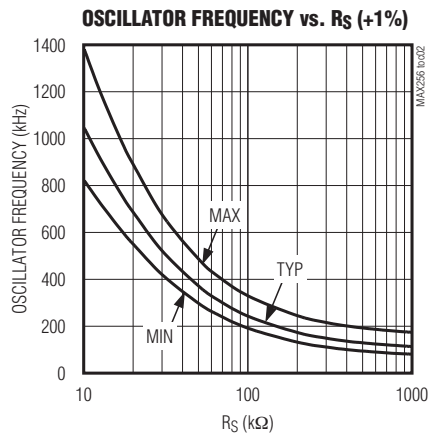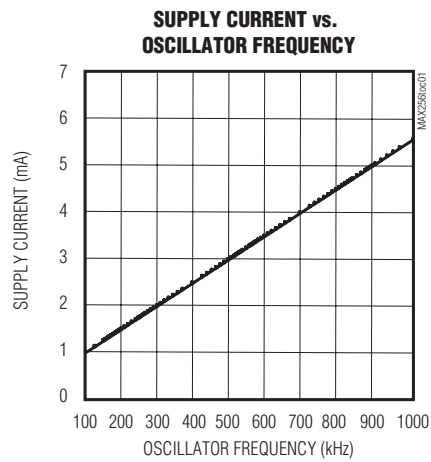**Note 3:** Minimum and maximum limits tested with ST1, ST2 unconnected.
Note 4: Total driver resistance includes the on-resistance of the top and the bottom internal FETs. If R_{OH} is the high-side resistance, and R_{OL} is the low-side resistance, R_{OHL} = R_{OH} + R_{OL}.

Pin Description

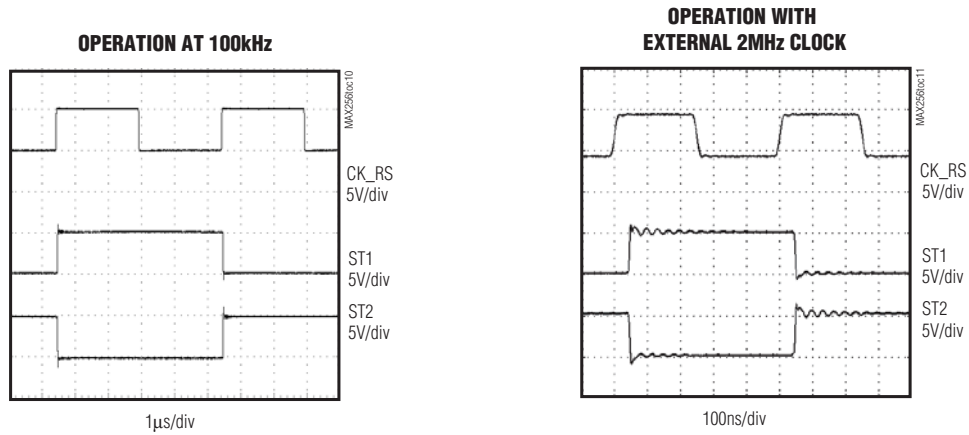| PIN	NAME	FUNCTION
1	CK_RS	Clock Input/Oscillator Frequency Adjust. When MODE is HIGH, set the internal oscillator frequency by connecting a 10kΩ or greater resistor from CK_RS to ground. When MODE is LOW, apply an external clock signal to CK_RS. The MAX256 outputs switch at one half the external clock frequency.
2, 3	V_{CC}	V_{CC} Supply Voltage, +3.0V ≤ V_{CC} ≤ +5.5V. Bypass V_{CC} to ground with a 4.7µF capacitor and a 470nF ceramic capacitor.
4	MODE	Mode Control Input. Drive MODE high to enable internal oscillator. Drive MODE low and supply a valid clock signal on CK_RS for external clock mode.
5	ST2	Transformer Drive Output 2
6, 7	GND	Ground
8	ST1	Transformer Drive Output 1
—	EP	EP is internally connected to GND. Connect to a large ground plane to maximize thermal performance; not intended as an electrical connection point.

Typical Operating Characteristics

(V_{CC} = +5.0V ±10%, T_A = +25°C, unless otherwise noted.) (See *Figure 8*)

SUPPLY CURRENT vs. OSCILLATOR FREQUENCY

OSCILLATOR FREQUENCY vs. R_S (+1%)

R_S vs. REQUIRED ET PRODUCT

OUTPUT VOLTAGE vs. OUTPUT CURRENT (TYPICAL APPLICATION FIGURE 8)

EFFICIENCY vs. OUTPUT CURRENT (TYPICAL APPLICATION FIGURE 8)

OUTPUT VOLTAGE vs. OUTPUT CURRENT (TYPICAL APPLICATION FIGURE 9)

EFFICIENCY vs. OUTPUT CURRENT (CIRCUIT OF FIGURE 9)

OUTPUT VOLTAGE vs. OUTPUT CURRENT (CIRCUIT OF FIGURE 10)
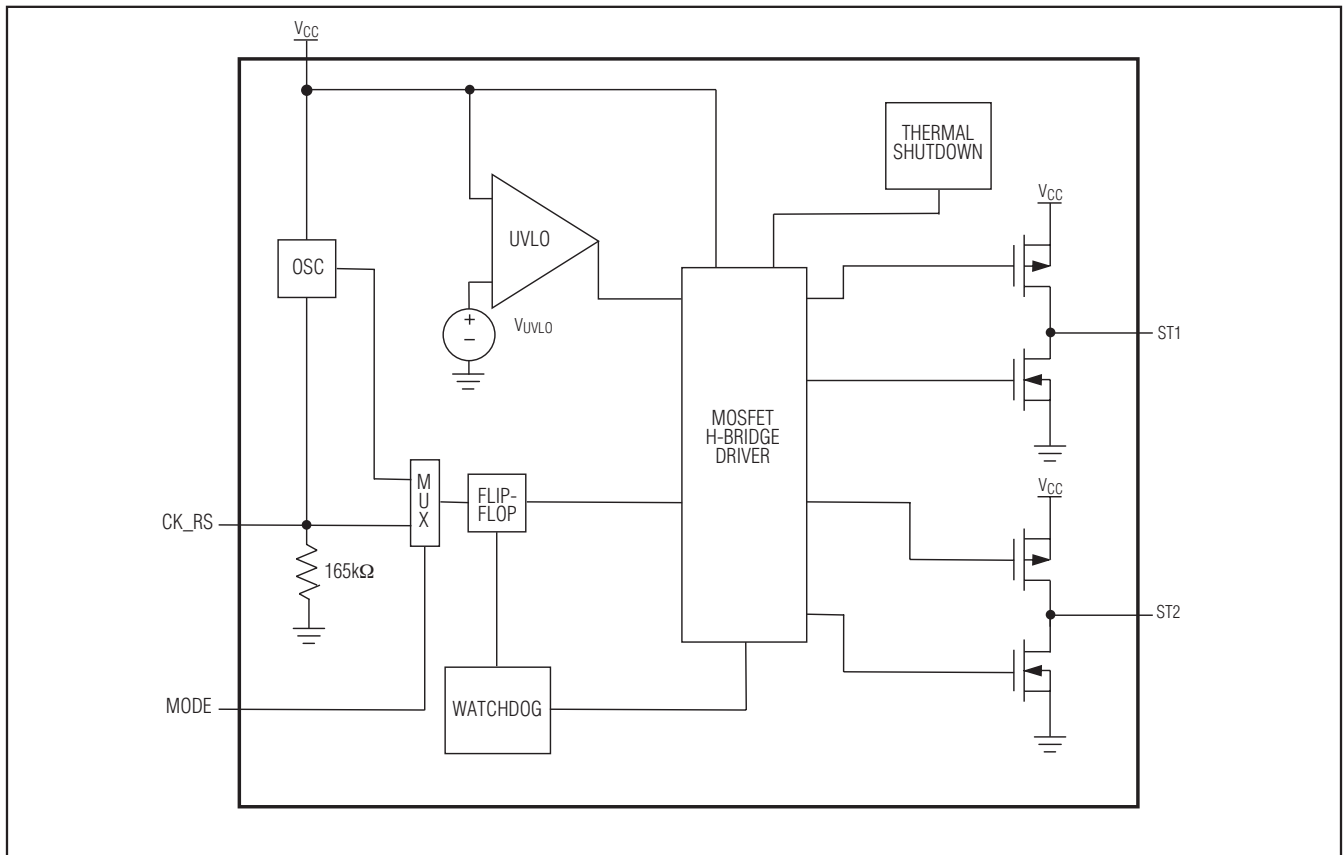
EFFICIENCY vs. OUTPUT CURRENT (CIRCUIT OF FIGURE 10)

Typical Operating Characteristics (continued)

(V_{CC} = +5.0V ±10%, T_A = +25°C, unless otherwise noted.) (See *Figure 8*)

OPERATION AT 100kHz

CK_RS
5V/div

ST1
5V/div

ST2
5V/div

1µs/div

**OPERATION WITH
EXTERNAL 2MHz CLOCK**

CK_RS
5V/div

ST1
5V/div

ST2
5V/div

100ns/div

Functional Diagram

Detailed Description

The MAX256 is an integrated primary-side controller and H-bridge driver for isolated power-supply circuits. The device contains an on-board oscillator, protection circuitry, and internal FET drivers to provide up to 3W of power to the primary winding of a transformer. The MAX256 can be operated using the internal programmable oscillator, or can be driven by an external clock for improved EMI performance. Regardless of the clock source being used, an internal flip-flop stage guarantees a fixed 50% duty cycle to prevent DC current flow in the transformer.

The MAX256 operates from a single-supply voltage of +5V or +3.3V, and includes undervoltage lockout for controlled startup. The device prevents cross-conduction of the H-bridge MOSFETs by implementing break-before-make switching. Thermal shutdown circuitry provides additional protection against damage due to overtemperature conditions.

Oscillator Modes

The MAX256 is driven by the internal programmable oscillator or an external clock. The logic state of MODE determines the clock source (see Table 1). Drive MODE high to select the internal resistor programmable oscillator. Drive MODE low to operate the MAX256 with an external clock signal on CK_RS.

Internal Oscillator Mode

The MAX256 includes a 100kHz to 1MHz programmable oscillator. Set the oscillator frequency by connecting CK_RS to ground with a 10kΩ or larger resistor. Leave CK_RS unconnected to set the oscillator to the minimum default frequency of 100kHz. CK_RS is internally pulled to ground with a 165kΩ resistor.

External Clock Mode

The MAX256 provides an external clock mode. When operating in external clock mode, an internal flip-flop divides the external clock by two in order to generate a switching signal with a guaranteed 50% duty cycle. As a result, the MAX256 outputs switch at one half the external clock frequency. The device switches on the rising edge of the external clock signal.

Watchdog

When the MAX256 is operating in external clock mode, a stalled clock could cause excessive DC current to flow through the primary winding of the transformer. The MAX256 features an internal watchdog circuit to prevent damage from this condition. The MAX256 is disabled when the external clock signal on CK_RS remains at the same logic level for longer than 55µs (max). The device resumes normal operation upon the next rising edge on CK_RS.

Disable Mode

When using the internal oscillator, drive MODE low to disable the MAX256. The device is disabled within 55µs after MODE goes low. When operating in external clock mode, suspend the clock signal for longer than 55µs to disable the MAX256. The device resumes normal operation when MODE is driven high or when the external clock signal resumes.

Power-Up and Undervoltage Lockout

The MAX256 provides an undervoltage lockout feature to ensure a controlled power-up state and prevent operation before the oscillator has stabilized. On power-up and during normal operation (if the supply voltage drops below 1.8V), the undervoltage lockout disables the device.

Thermal Shutdown

The MAX256 is protected from overtemperature damage by a thermal shutdown circuit. When the junction temperature (T_J) exceeds +165°C, the device is disabled. The device resumes normal operation when T_J falls below +155°C.

ESD Protection

As with all Maxim devices, ESD-protection structures are incorporated on all pins to protect against electrostatic discharges encountered during handling and assembly.

ESD Test Conditions

ESD performance depends on a variety of conditions. Please contact Maxim for a reliability report documenting test setup, methodology, and results.

Table 1. Oscillator Modes

OSCILLATOR MODE	CK_RS	MODE	OPERATION
Internal Programmable Frequency	Unconnected or pulled to ground by R_S. R_S must be greater than 10kΩ.	V_{CC}	100kHz to 1MHz (typ). Leave CK_RS unconnected for minimum switching frequency.
External Clock	Digital input. Drive CK_RS with an external clock signal.	Ground	CK_RS is pulled to ground by an internal 165kΩ resistor. The device switches at one half the external clock frequency.
Disable	Connected to V_{CC} or GND (external clock mode)	Ground	The device is disabled after a maximum of 55µs following the last rising edge on CK_RS.
	Unconnected or pulled to ground with R_S (internal clock mode)		

Applications Information

Available Output Power

With a supply voltage of +5V over the extended -40°C to +85°C temperature range, the MAX256 is specified to provide up to 3W of power to the primary side of a transformer in an isolated power supply. The device provides up to 2.5W of power to the primary winding over the +85°C to +125°C temperature range. The output power is specified at ST1 and ST2 since losses in the transformer and rectification network are dependent upon component selection and topology. The power dissipation of the MAX256 is approximated by:

$$P_D = R_{OHL} \times I_{PRI}^2$$

where R_{OHL} is the total high-side and low-side on-resistance of the internal FET drivers, and I_{PRI} is the load current flowing through the transformer primary between ST1 and ST2. For low output load currents, include the contribution to P_D from the quiescent supply current:
$$I_{CC} \times V_{CC}.$$

PC Board Layout Guidelines

As with all power-supply circuits, careful PC board layout is important to achieve low switching losses and stable operation. For thermal performance, connect the exposed paddle to a solid copper ground plane.

The traces from ST1 and ST2 to the transformer must be low-resistance and inductance paths. Place the transformer as close as possible to the MAX256 using short, wide traces.

When the device is operating with the internal oscillator, it is possible for high-frequency switching components on ST1 and ST2 to couple into the CK_RS circuitry
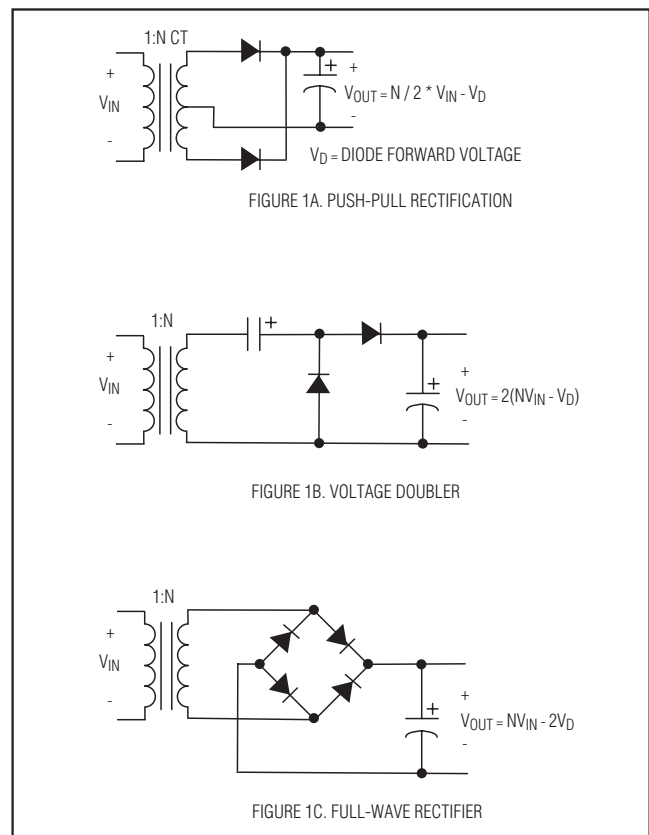

FIGURE 1A. PUSH-PULL RECTIFICATION

$V_{OUT} = N / 2 * V_{IN} - V_D$

$V_D = $ DIODE FORWARD VOLTAGE

FIGURE 1B. VOLTAGE DOUBLER

$V_{OUT} = 2(NV_{IN} - V_D)$

FIGURE 1C. FULL-WAVE RECTIFIER

$V_{OUT} = NV_{IN} - 2V_D$

Figure 1. Secondary-Side Rectification Topologies

through PC board parasitic capacitance. This capacitive coupling can induce duty-cycle errors in the oscillator, resulting in a DC current through the transformer. To ensure proper operation, shield the CK_RS circuitry

from ST1 and ST2 by placing a grounded trace between these circuits. Place R_S as close as possible to the CK_RS pin. An additional capacitance of 100nF from CK_RS to GND may be required in some applications.

Output Voltage Regulation

For many applications, the unregulated output of the MAX256 meets the supply voltage tolerances. This configuration represents the highest efficiency possible with the MAX256.

For applications requiring a regulated output voltage, Maxim provides several solutions. In the following examples, assume a tolerance of ±10% variation for the input voltage.

When a full-bridge power supply is operated under maximum input voltage and low output load current, the voltage at the output of the rectifier network can exceed the absolute maximum input voltage of the low dropout regulator (LDO). If the minimum output load current is less than approximately 5mA, connect a zener diode from the output voltage to ground (as shown in Figure 2) to limit the output to a safe value.

+3.3V to Isolated, Regulated +5.0V

In the circuit of Figure 2, the MAX1659 LDO regulates the output of the MAX256 to +5V. The Halo TGM-H281NF provides a center-tapped 1:2.6 turns ratio, and the secondary circuit implements a 4-diode bridge rectifier (Figure 1C).

For a minimum input voltage of +3.0V, the output voltage of the bridge rectifier is approximately +5.5V at a current of 200mA. A 15V zener diode protects the LDO from high input voltages, but adds a few microamps to the no-load input current of the MAX256.

+5V to Isolated, Regulated +3.3V

In Figure 3, the MAX1658 LDO is used with the TGM-H281NF transformer and a 2-diode push-pull rectifier (Figure 1A). This topology produces approximately +4.5V at a current of 350mA. The MAX1658 produces a regulated +3.3V output voltage.

+5V to Isolated, Regulated +12V

In Figure 4, the 7812 LDO is used with the TGM-H281NF transformer and the voltage doubler network (Figure 1B). This circuit produces approximately +12.5V at a load current of 150mA. The 7812 produces a regulated +12V output.

+5V to Isolated, Regulated ±15V

In Figure 5, the MAX256 is used with two TGM-280NS transformers and voltage doubler networks (Figure 1B) to supply 20V to a pair of 7815 regulators. The circuit produces a regulated ±15V at 50mA.

Isolated DAC/ADC Interface for Industrial Process Control

The MAX256 provides isolated power for data converters in industrial process control applications (Figure 6). The 3W isolated power output capability allows for data converters operating across multiple isolation barriers. The power output capability also supports circuitry for signal conditioning and multiplexing.

Isolated RS-485/RS-232 Data Interfaces

The MAX256 provides power for multiple transceivers in isolated RS-485/RS-232 data interface applications. The 3W isolated power output capability of the MAX256 allows more than ten RS-485 transceivers simultaneously.

Isolated Power Supply

The MAX256 allows a versatile range of secondary-side rectification circuits (see Figure 1). The secondary transformer winding can be wound to provide a wide range of isolated voltages. The MAX256 delivers 3W of power to the transformer with a +5V supply (-40°C to +85°C). The MAX256 produces up to 2.5W over the +85°C to +125°C temperature range. For a supply voltage of +3.3V, the MAX256 delivers 2W of power to the transformer over the -40°C to +85°C temperature range, and 1.4W between +85°C and +125°C. Figure 8 shows a +5V to isolated +5V application that delivers up to 500mA. In Figure 9, the MAX256 is configured to provide +5V from a +3.3V supply at 350mA, and in Figure 10, the MAX256 provides isolated +15V and -15V at a total current up to 75mA.

The MAX256 provides the advantages of the full-bridge converter topology, including multiple isolated outputs, step-up/step-down or inverted output, relaxed filtering requirements, and low output ripple.

Power-Supply Decoupling

Bypass V_{CC} to ground with a 0.47µF ceramic capacitor as close to the device as possible. Additionally, place a 4.7µF capacitor from V_{CC} to ground.

Exposed Paddle

Ensure that the exposed paddle is soldered to the bottom layer ground for best thermal performance. Failure to provide a low thermal impedance path to the ground plane will result in excessive junction temperatures when delivering maximum output power.
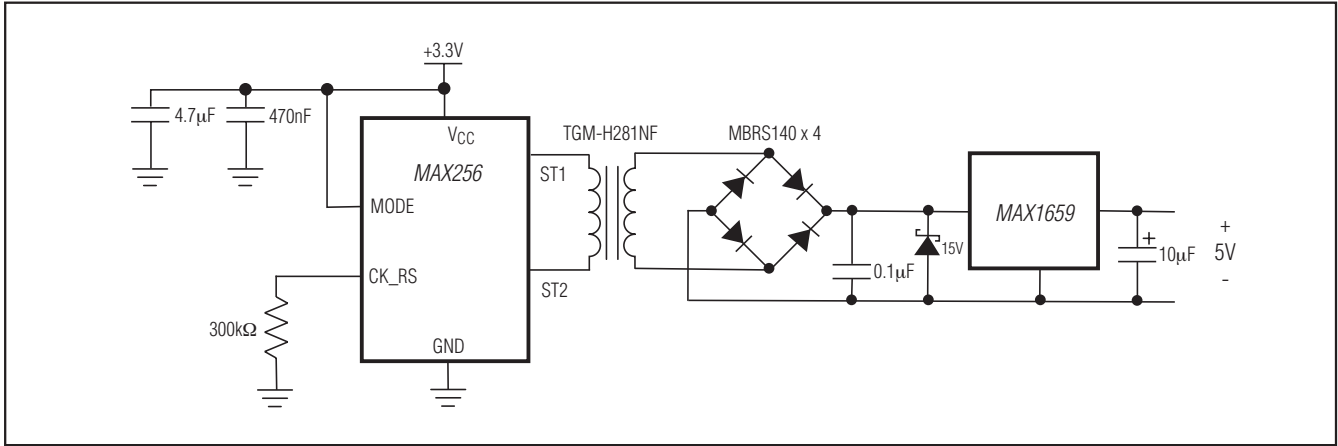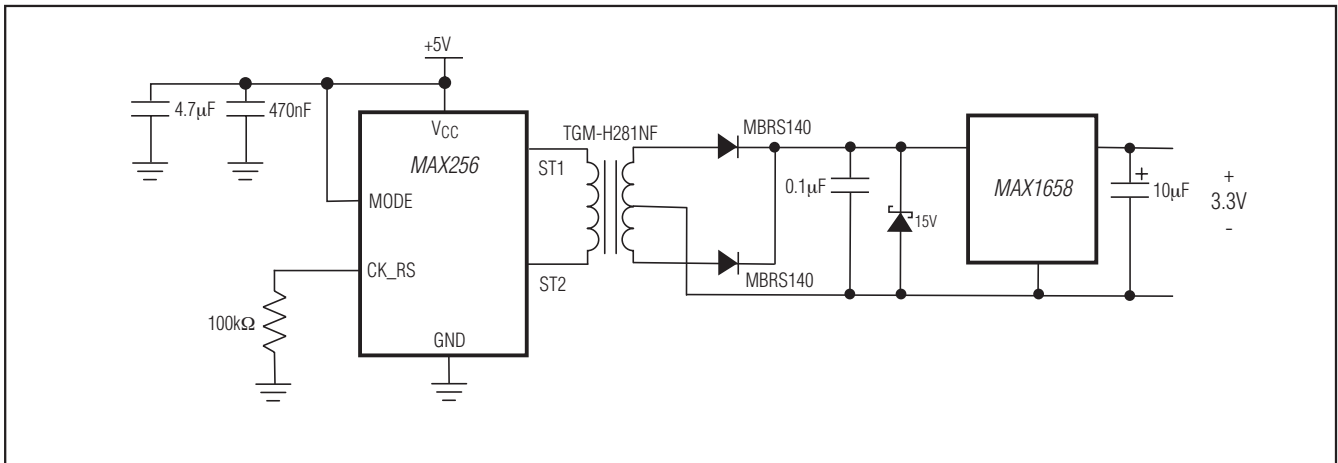
Figure 2. +3.3V to Isolated Regulated +5V

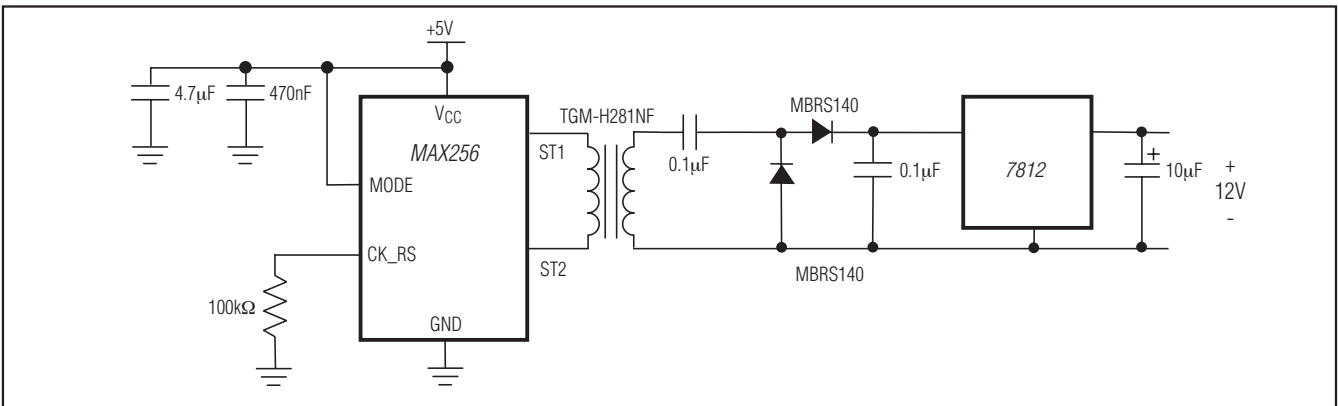Figure 3. +5V to Isolated Regulated +3.3V
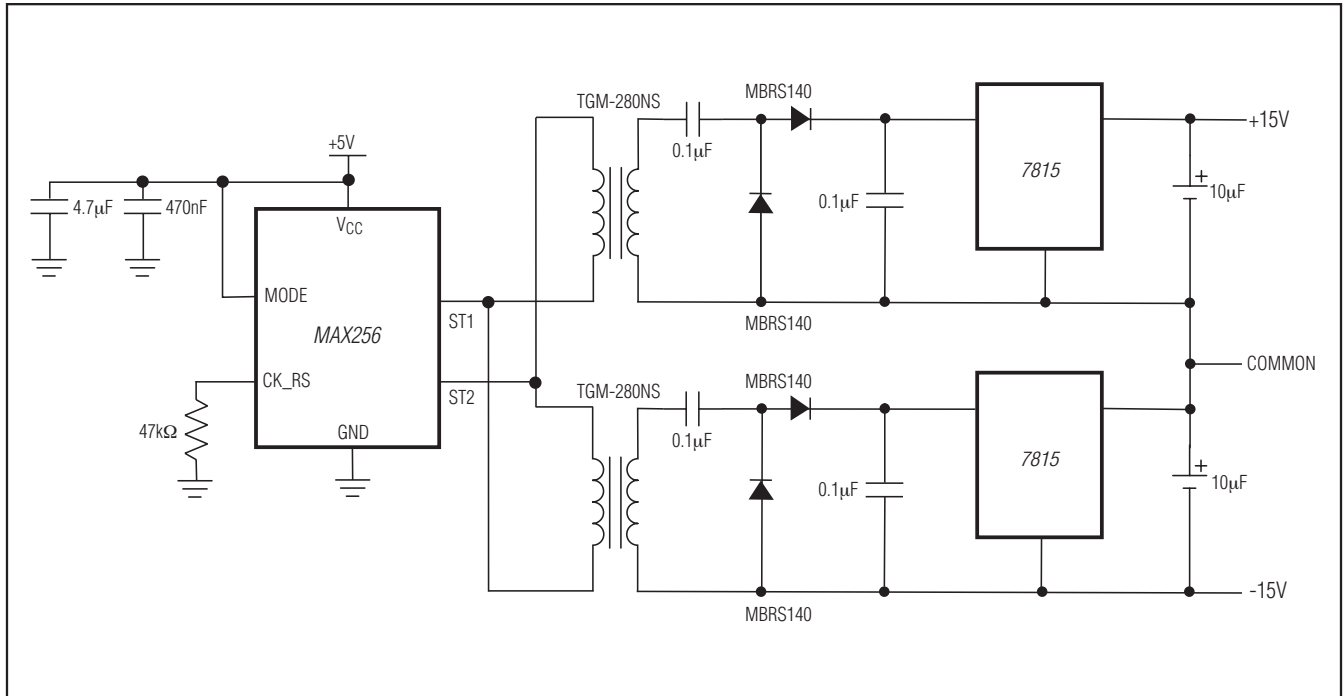

Figure 4. +5V to Isolated Regulated +12V

Figure 5. +5V to Isolated Regulated ±15V

Component Selection

Transformer Selection

Transformer selection for the MAX256 can be simplified by the use of a design metric, the ET product. The ET product relates the maximum allowable magnetic flux density in a transformer core to the voltage across a winding and switching period. Inductor current in the primary linearly increases with time in the operating region of the MAX256. Transformer manufacturers specify a minimum ET product for each transformer. For the MAX256, the requirement on ET product is calculated as:

$$ET = V_{CC} \times \frac{1}{2 \times f_{SW}}$$

By choosing a transformer with sufficient ET product in the primary winding, it is ensured that the transformer will not saturate during operation. Saturation of the magnetic core results in significantly reduced inductance of the primary, and therefore a large increase in current flow. Excessive transformer current results in a temperature rise and possible damage to the transformer and/or the MAX256.

When CK_RS is unconnected, the internal oscillator is programmed for the minimum frequency. The default required ET product for the MAX256 is 42.3Vµs, (assuming +5.5V maximum VCC), or 27.7Vµs for +3.3V operation (assuming +3.6V maximum VCC). Both of these ET products assume the minimum oscillator frequency of 65kHz. See the *Typical Operating Characteristics* plot, R_S vs. Required ET Product to determine the required ET product for a given value of R_S.

In addition to the constraint on ET product, choose a transformer with a low DC-winding resistance. Power dissipation of the transformer due to the copper loss is approximated as:

$$P_{D\_TX} = I_{LOAD}^2 \times \left(N^2 R_{PRI} + R_{SEC} \right)$$

where R_{PRI} is the DC-winding resistance of the primary, and R_{SEC} is the DC-winding resistance of the secondary. In most cases, an optimum is reached when:

$$R_{SEC} = N^2 R_{PRI}$$

For this condition, the power dissipation is equal for the primary and secondary windings.
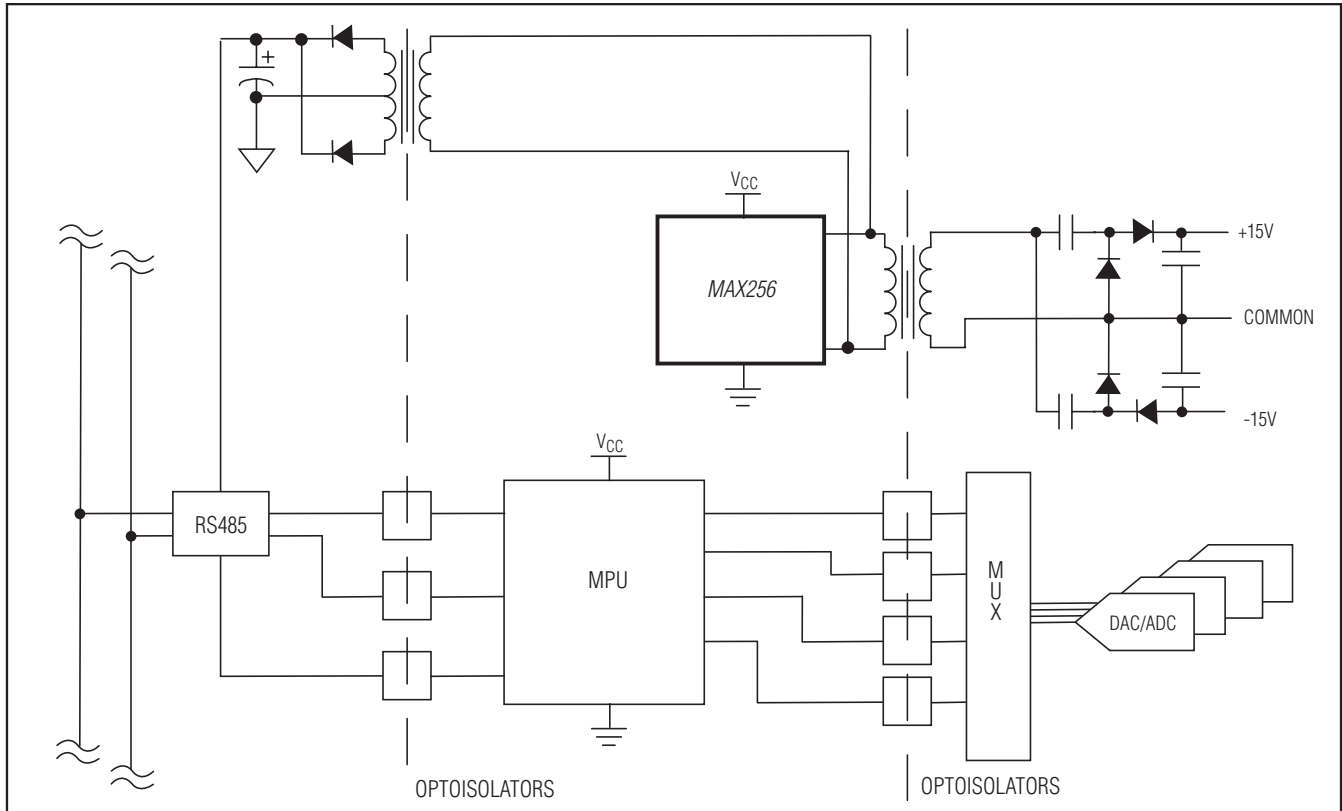
Figure 6. Isolated Power Supply for Process Control Applications

As with all power-supply designs, it is important to optimize efficiency. In designs incorporating small transformers, the possibility of thermal runaway makes low transformer efficiencies problematic. Transformer losses produce a temperature rise that reduces the efficiency of the transformer. The lower efficiency, in turn, produces an even larger temperature rise.

To ensure that the transformer meets these requirements under all operating conditions, the design should focus on the worst-case conditions. The most stringent demands on ET product arise for minimum switching frequency, maximum input voltage, maximum temperature, and load current. Additionally, the worst-case values for transformer and rectifier losses should be considered.

The primary should be a single winding; however, the secondary can be center-tapped, depending on the desired rectifier topology. In most applications, the phasing between primary and secondary windings is not significant. Half-wave rectification architectures are possible with the MAX256; however, these are discouraged. If a net DC current results due to an imbalanced load, the magnetic flux in the core is increased. This reduces the effective ET product and can lead to saturation of the transformer core.

Transformers for use with the MAX256 are typically wound on a high-permeability magnetic core. To minimize radiated electromagnetic emissions, select a toroid, pot core, E/I/U core, or equivalent.

+3.3V Operation
The MAX256 can be operated from a +3.3V supply by increasing the turns ratio of the transformer, or by designing a voltage-doubler or voltage-tripler circuit as shown in Figure 1B.

Optimum performance at +3.3V is obtained with fewer turns on the primary winding, since the ET product is lower than for a +5V supply. However, any of the transformers for use with a +5V supply will operate properly with a +3.3V supply. For a given power level, the transformer currents are higher with a +3.3V supply than with a +5V supply. Therefore, the DC resistance of the transformer windings has a larger impact on the circuit efficiency.
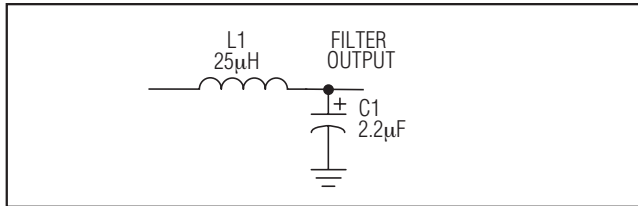
Figure 7. Output Ripple Filter

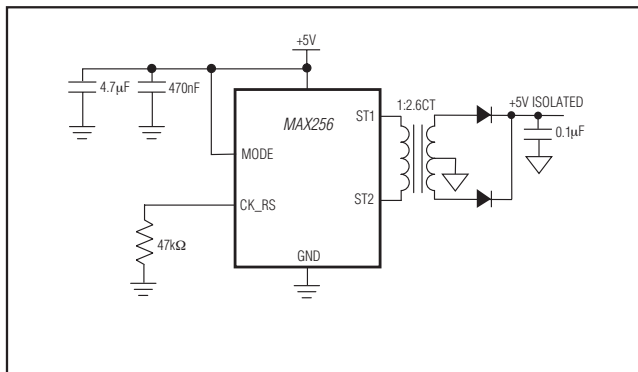
Figure 8. +5V to Isolated +5V
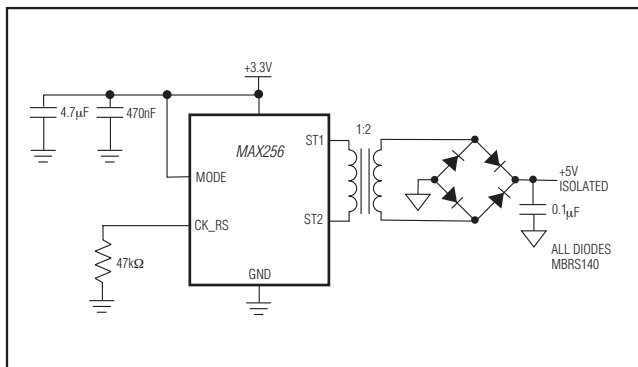

Figure 9. +3.3V to Isolated +5V

Figure 10. +5V to Isolated ±15V

Low-Power Applications and Multiple Transformers

For more information about transformer selection, please refer to the MAX3535E data sheet. The MAX3535E uses a transformer in a similar topology. See Tables 3, 4, and 5 in the MAX3535E data sheet for a list of commercially available transformers. These transformers are preferred for lower power applications and are suitable for use with the MAX256 up to the power limits of the transformers. Alternatively, the MAX256 can drive the primaries of two or more low-power transformers to provide multiple isolated outputs. One or more of the manufacturers listed in the MAX3535E data s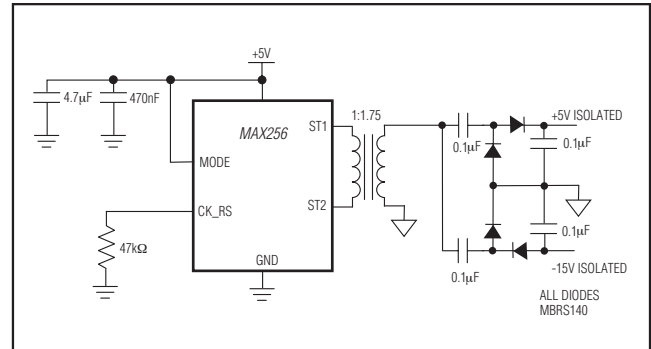heet may produce a custom trans-former for specific applications. Contact the individual transformer suppliers for details.

Diode Selection

The high switching speed of the MAX256 necessitates high-speed rectifiers. Ordinary silicon signal diodes such as 1N914 or 1N4148 may be used for low-output current levels (less than 50mA). At higher output currents, select low forward-voltage Schottky diodes to improve efficiency. Ensure that the average forward current rating for the rectifier diodes exceeds the maximum load current of the circuit. For surface-mount applications, Schottky diodes such as the BAT54, MBRS140 and MBRS340 are recommended.

Capacitor Selection

Input Bypass Capacitor

Bypass the supply voltage to GND with a 0.47µF ceramic capacitor as close to the device as possible. Additionally, connect a 4.7µF or greater capacitor to provide input voltage filtering. The equivalent series resistance (ESR) of the input capacitors is not as critical as for the output capacitors. Typically, ceramic X7R capacitors are adequate.

Output Filter Capacitor

In most applications, the actual capacitance rating of the output filter capacitor is less critical than the capacitor's ESR. In applications sensitive to output voltage ripple, the output filter capacitor must have low ESR. For optimal performance, the capacitance should meet or exceed the specified value over the entire operating temperature range. Capacitor ESR typically rises at low temperatures; however, OS-CON capacitors can be used at temperatures below 0°C to help reduce output voltage ripple in sensitive applications. In applications where low output-voltage ripple is not critical, standard ceramic 0.1µF capacitors are sufficient.

Table 2. Suggested External Component Manufacturers

MANUFACTURER	COMPONENT	WEBSITE	PHONE
Central Semiconductor	diodes	www.centralsemi.com	631-435-1110
Halo Electronics	transformers	www.haloelectronics.com	650-903-3800
Kemet	capacitors	www.kemet.com	864-963-6300
Sanyo	capacitors	www.sanyo.com	619-661-6835
Taiyo Yuden	capacitors	www.t-yuden.com	408-573-4150
TDK	capacitors	www.component.tdk.com	888-835-6646

Output-Ripple Filtering

Output voltage ripple can be reduced with a lowpass LC pi-filter (Figure 7). The component values shown give a cutoff frequency of 21.5kHz by the equation:

$$f_{3dB} = \frac{1}{2\pi\sqrt{LC}}$$

Use an inductor with low DC resistance and sufficient saturation current rating to minimize filter power dissipation.

Chip Information

PROCESS: BiCMOS

Package Information

For the latest package outline information and land patterns (footprints), go to **www.maximintegrated.com/packages**. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

PACKAGE TYPE	PACKAGE CODE	OUTLINE NO.	LAND PATTERN NO.
8 SO-EP	S8E+12	**21-0111**	**90-0150**

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	8/05	Initial release	—
1	3/12	Added automotive-qualified part information. Added lead-free packaging information	1–4, 8, 12
2	2/15	Added the *Benefits and Features* section	1

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