High-Speed Quad RS-485/RS-422 Receivers with ±65V Fault-Tolerant Inputs

MAX33076E/MAX33078E

General Description

The MAX33076E/MAX33078E are 20Mbps robust quad-channel RS-485/RS-422 receivers with extended ±25V input common-mode operating range (CMR), ±65V fault-tolerant inputs, and ±25kV ESD for harsh electrical environments. Both devices operate with a +3.3V or +5V supply rail.

These devices feature an extended ±25V CMR, which ensures that the MAX33076E/MAX33078E reliably receive data when the ground planes between two nodes have large differences or when interference may couple onto the bus from motors or other electrical noise sources. The ±65V fault-tolerant A and B inputs ensure the device is protected when data lines are shorted to external power supplies. The ±25kV ESD tolerance provides added protection on the receiver inputs from ESD strikes during production or in the field.

The MAX33076E/MAX33078E feature true fail-safe circuitry where the receiver output is set high when receiver inputs are open, shorted, or connected to a terminated transmission line with all drivers disabled.

The receiver enable inputs (G and $\overline{G}$) on the MAX33076E enable or disable all outputs. The MAX33076E is pin-compatible with the MAX3095/MAX3096 while offering improved performance and protection features.

The EN12 and EN34 pins on the MAX33078E enable the Y1/Y2 and Y3/Y4 outputs, respectively. The MAX33078E is an upgrade to the MAX3093E/MAX3094E, offering improved performance and protection features.

The MAX33076E and MAX33078E are available in 16-pin SOIC and QSOP packages and are rated over the entire -40°C to +125°C operating temperature range.

Applications

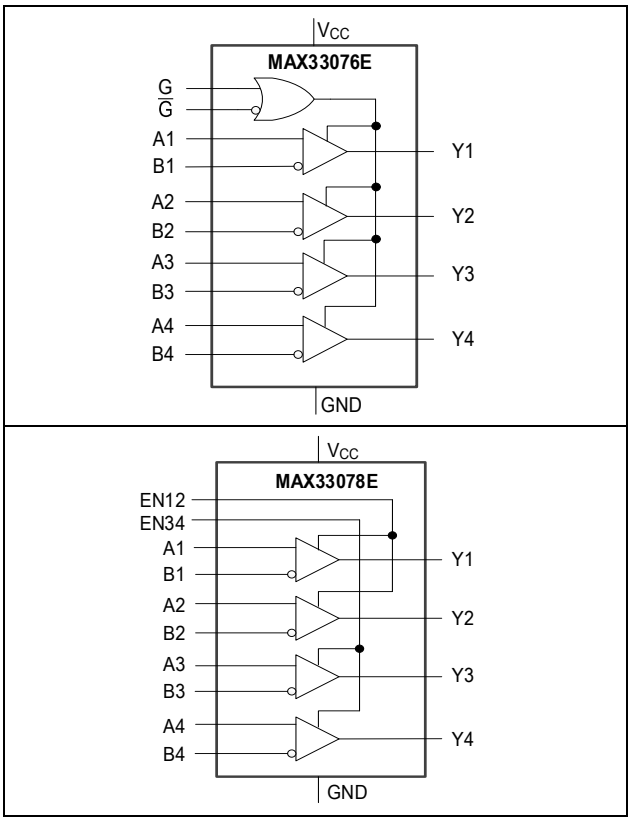
- Motor Controllers
- Encoder Interfaces
- Servo Control Communication

Ordering Information appears at end of data sheet.

Benefits and Features

- Integrated Protection Increases Robustness
  - ±65V Fault-Tolerant Quad Receiver Inputs
  - ±25kV ESD (Human Body Model)
  - ±25V Common-Mode Range
  - True Fail-Safe Receiver Prevents False Transition on Receiver Input Short or Open
  - -40°C to +125°C Operating Temperature Range
- Increased Flexibility Simplifies Design
  - Data Rate up to 20Mbps
  - Allows up to 128 Receivers on the Bus
  - Operates with +3.3V to +5V Supply Rail
- Industrial Standard Compatible for Easy Upgrades
  - 16-Pin SOIC and QSOP Packages
  - Cost-Effective Upgrade to Industry Standard MAX3093E/MAX3094E and MAX3095/MAX3096

Simplified Block Diagram



19-101206; Rev 1; 7/24

Absolute Maximum Ratings

V_{CC} to GND ..... -0.3V to +6V

Y_ to GND.....-0.3V to (V_{CC} + 0.3)V

G, $\overline{G}$, EN12, EN34 to GND ..... -0.3V to +6V

A_, B_ to GND ..... -70V to +70V

Short-Circuit Duration (Y_, A_, B_) to GND..... Continuous

Continuous Power Dissipation

16-Pin SOIC (T_A = +70°C, derate 13.3mW/°C above +70°C) 1066.7mW

16-Pin QSOP (T_A = +70°C, derate 9.52mW/°C above +70°C)..... 761.9mW

Temperature Ratings

Operating Temperature Range..... -40°C to +125°C

Maximum Junction Temperature.....+150°C

Storage Temperature Range..... -60°C to +150°C

Lead Temperature (Soldering 10s) .....+300°C

Reflow Temperature .....+260°C

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 Information

16 QSOP

Package Code	E16+11C
Outline Number	*21-0055*
Land Pattern Number	*90-0167*
Thermal Resistance, Four-Layer Board	
Junction-to-Ambient (θ_{JA})	105°C/W
Junction-to-Case Thermal Resistance (θ_{JC})	37°C/W

16 SOIC

Package Code	S16+1C
Outline Number	*21-0041*
Land Pattern Number	*90-0097*
Thermal Resistance, Four-Layer Board	
Junction-to-Ambient (θ_{JA})	75.0°C/W
Junction-to-Case Thermal Resistance (θ_{JC})	24.0°C/W

For the latest package outline information and land patterns (footprints), go to *www.analog.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 thermal resistances were obtained using both the four-layer EV kit as well as the method described in JEDEC specification JESD51-7. For detailed information on package thermal considerations, refer to *www.analog.com//thermal-tutorial.*

19-101206; Rev 1; 7/24

Electrical Characteristics

(V_{CC} = 3.0V to 5.5V, T_A = -40°C to +125°C, unless otherwise specified. Typical values are at V_{CC} = 5V and T_A = 25°C.) (*Note 1*, *Note 2*)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
POWER SUPPLY							
Power Supply	V_{CC}			3.0		5.5	V
Supply Current	I_{CC}	G = high, $\overline{G}$ = low (MAX33076E) EN12 = high, EN34 = high (MAX33078E), no switching, no load			9	15	mA
Shutdown Current	I_{SHDN}	G = low, $\overline{G}$ = high (MAX33076E) EN12 = low, EN34 = low (MAX33078E), all channels disabled			400	650	µA
RECEIVER							
Common-Mode Range	V_{CM}			-25		+25	V
Differential Input Threshold	V_{TH}	-25V ≤ V_{CM} ≤ +25V		-200		+200	mV
Input Hysteresis	V_{INHYS}	-25V ≤ V_{CM} ≤ +25V			200		mV
Input Current (A_, B_)	I_{IN}	V_{CC} = 0V or 5.5V	V_{IN} = -25V			-520	µA
			V_{IN} = +25V			+520	
Input Resistance	R_{IN}			48			kΩ
LOGIC INPUTS (G, $\overline{G}$, EN12, EN34)							
Enable Input Current	I_{INEN}					±1	µA
Enable Input High Voltage	V_{IH}			2			V
Enable Input Low Voltage	V_{IL}					0.8	V
LOGIC OUTPUTS (Y_)							
Output High Voltage	V_{OH}	V_{ID} = 200mV, I_{OUT} = -3mA		V_{CC} – 0.4			V
Output Low Voltage	V_{OL}	V_{ID} = -200mV, I_{OUT} = +3mA				0.4	V
Short-Circuit Current	I_{SC}			-80		+80	mA
PROTECTION							
Thermal Shutdown Threshold	T_{SHDN}	Temperature rising			+160		°C
Thermal Shutdown Hysteresis	T_{HYST}				12		°C
ESD Protection (A_, B_)		Human Body Model			±25		kV
		IEC 61000-4-2 Air Gap Discharge to GND			±4		
		IEC 61000-4-2 Contact Discharge to GND			±4		
ESD Protection (All Other Pins)		Human Body Model			±4		kV
		Charge Device Model			±4		
Fault Protection Range (A_, B_ Pins to GND)		A_, B_ independently or simultaneously		-65		+65	V
SWITCHING CHARACTERISTICS (*Note 3*)							
Data Rate				20			Mbps
Propagation Delay	t_{PLH}, t_{PHL}	*Figure 1*				75	ns

(V_{CC} = 3.0V to 5.5V, T_A = -40°C to +125°C, unless otherwise specified. Typical values are at V_{CC} = 5V and T_A = 25°C.) (*Note 1*, *Note 2*)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Propagation-Delay Skew	t_{SK}	$\lvert t_{PHL} - t_{PLH} \rvert$			20	ns
Output Enable Time to Low Level	t_{ZL}	R_L = 1kΩ, C_L = 15pF, *Figure 2*			100	ns
Output Enable Time to High Level	t_{ZH}	R_L = 1kΩ, C_L = 15pF, *Figure 2*			2000	ns
Output Disable Time from Low Level	t_{LZ}	R_L = 1kΩ, C_L = 15pF, *Figure 2*			400	ns
Output Disable Time from High Level	t_{HZ}	R_L = 1kΩ, C_L = 15pF, *Figure 2*			400	ns
Time to Fail-Safe	t_{FS}	(*Note 4*)		10		µs

Note 1: All devices are 100% production tested at T_A = +25°C. Specifications over temperature are guaranteed by design.

Note 2: All currents into the device are positive; all currents out of the device are negative. All voltages are referred to device ground, unless otherwise noted.

Note 3: Guaranteed by design. Not production tested.

Note 4: When the differential input voltage ($V_{A\_} - V_{B\_}$) is 0V for at least 10µs (typ), the output, Y_, is set to a logic-high voltage. See the *True Fail-Safe* section for more information.

Test Circuits and Timing Diagrams

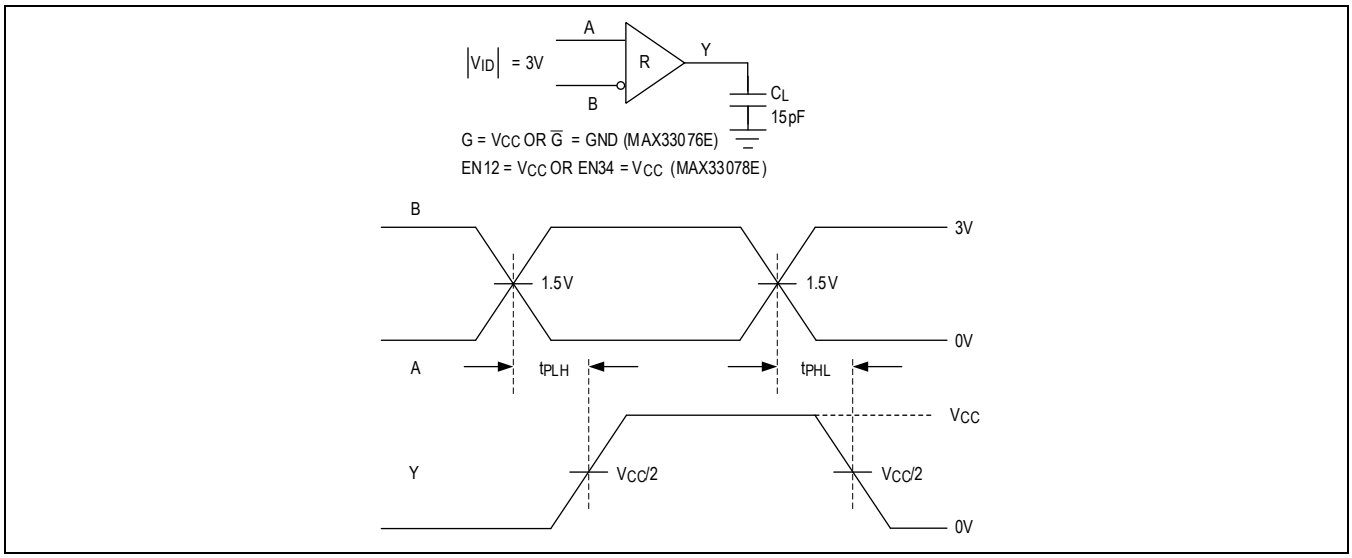


Figure 1. Receiver Propagation Delay

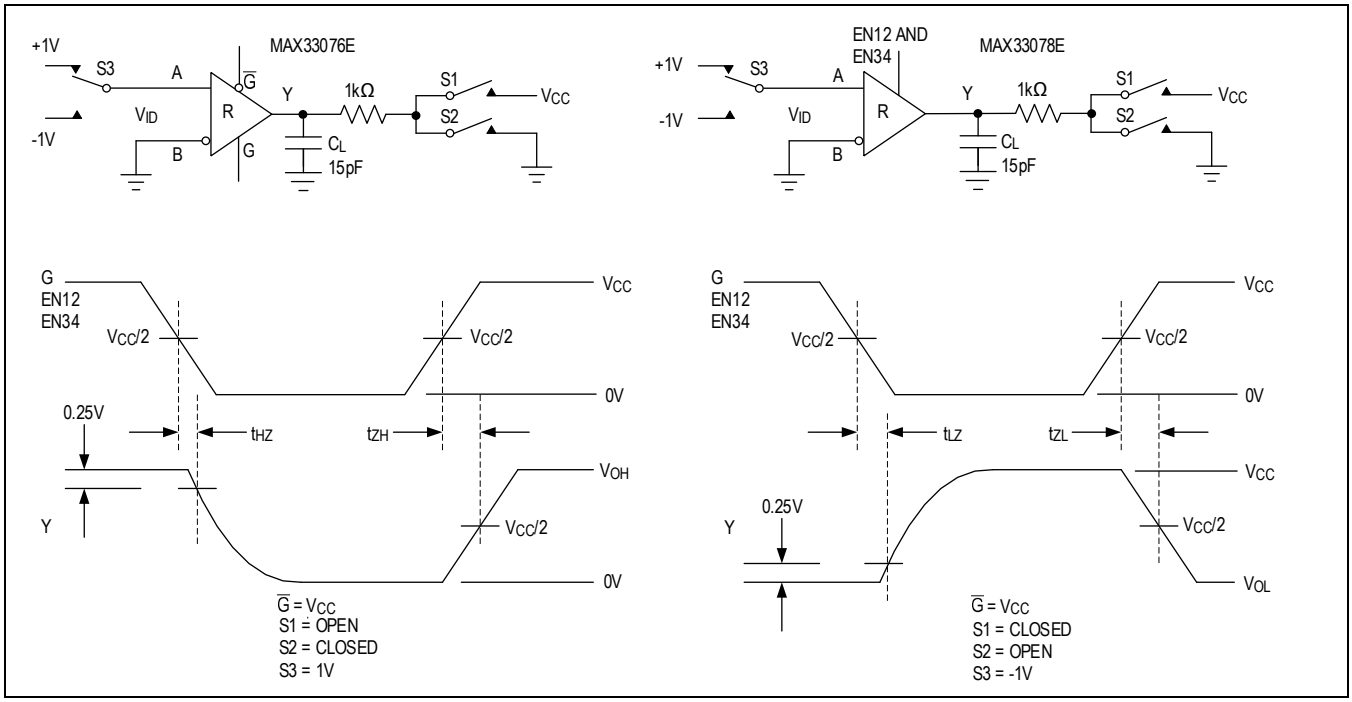
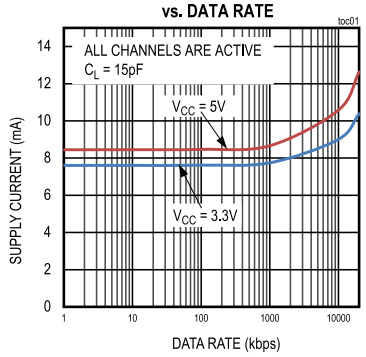


Figure 2. Receiver Enable and Disable Times

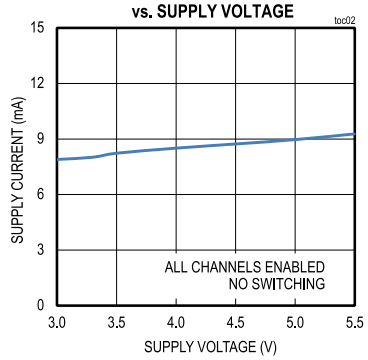
Typical Operating Characteristics

(V_{CC} = 5V, T_A = +25°C, unless otherwise noted.)

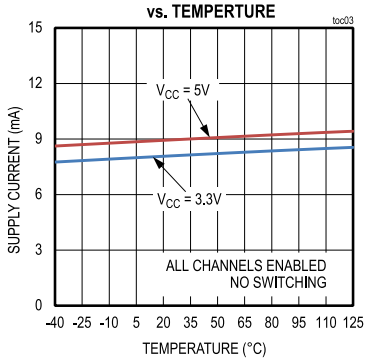
SUPPLY CURRENT vs. DATA RATE



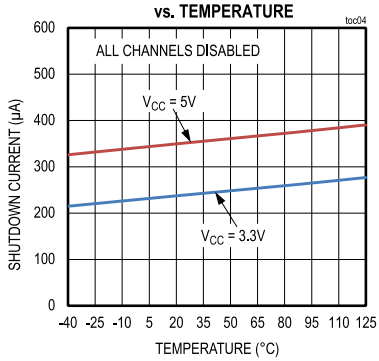
QUIESCENT CURRENT vs. SUPPLY VOLTAGE



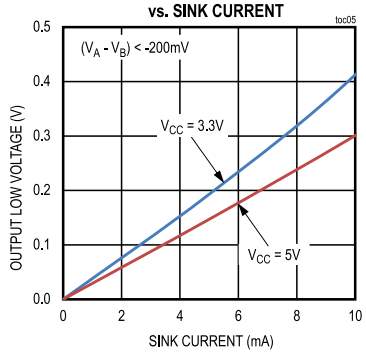
QUIESCENT CURRENT vs. TEMPERTURE



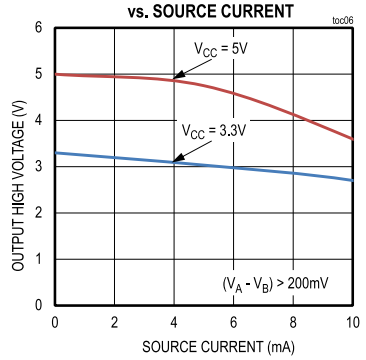
SHUTDOWN CURRENT vs. TEMPERATURE



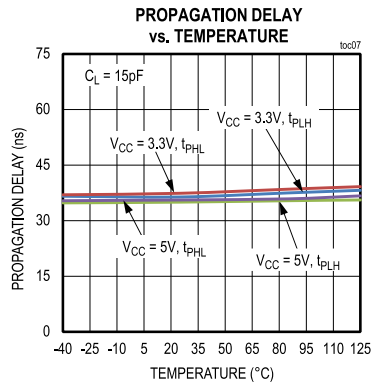
Y_ OUTPUT LOW VOLTAGE vs. SINK CURRENT



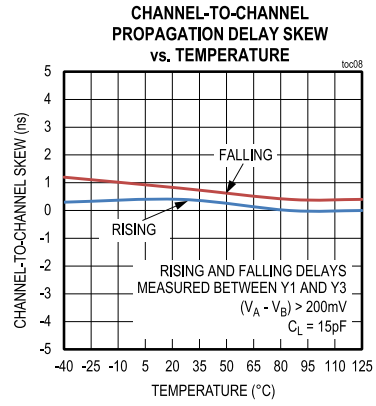
Y_ OUTPUT HIGH VOLTAGE vs. SOURCE CURRENT



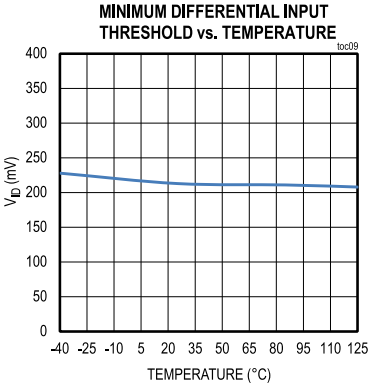
PROPAGATION DELAY vs. TEMPERATURE

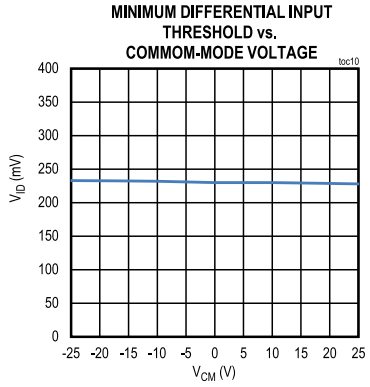


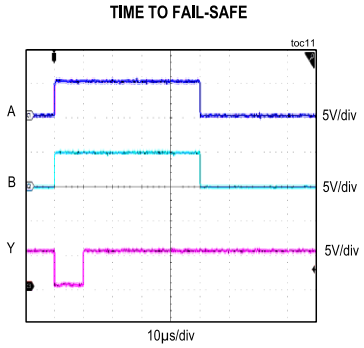
CHANNEL-TO-CHANNEL PROPAGATION DELAY SKEW vs. TEMPERATURE



MINIMUM DIFFERENTIAL INPUT THRESHOLD vs. TEMPERATURE

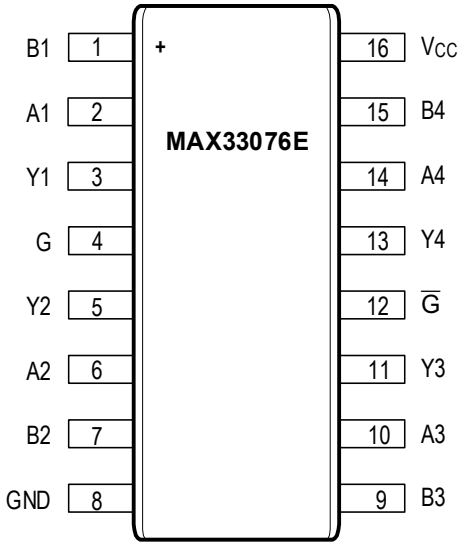



MINIMUM DIFFERENTIAL INPUT THRESHOLD vs. COMMOM-MODE VOLTAGE
toc10
400
350
300
250
200
150
100
50
0
V_{ID} (mV)
-25 -20 -15 -10 -5 0 5 10 15 20 25
V_{CM} (V)


TIME TO FAIL-SAFE
toc11
A
B
Y
5V/div
5V/div
5V/div
10µs/div

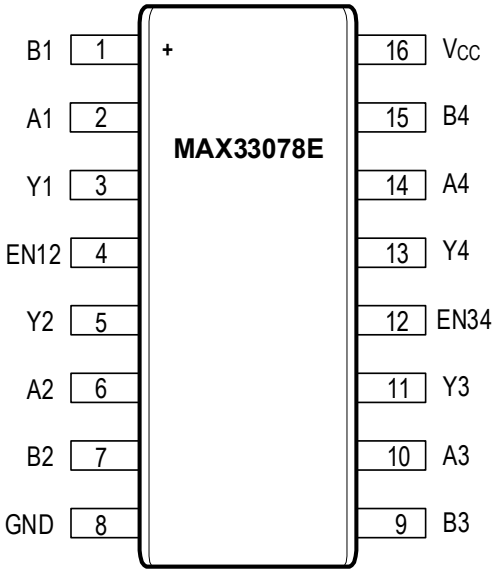
Pin Configurations

MAX33076E



SOIC/QSOP

MAX33078E



SOIC/QSOP

Pin Descriptions

PIN		NAME	FUNCTION
MAX33076E	MAX33078E		
1	1	B1	Inverting Receiver Input for Channel 1
2	2	A1	Noninverting Receiver Input for Channel 1
3	3	Y1	Receiver Channel 1 Output. See *Function Tables* for more Information.
4	—	G	Receiver Enable. A logic-high on this input enables all receivers. When G = low and $\overline{G}$ = high, the device is in low-power shutdown mode.
—	4	EN12	Receiver Enable for Channel 1 and 2. Pull EN12 high to enable Channel 1 and 2 receivers. When EN12 = low and EN34 = low, the device is in low-power shutdown mode.
5	5	Y2	Receiver Channel 2 Output
6	6	A2	Noninverting Receiver Input for Channel 2
7	7	B2	Inverting Receiver Input for Channel 2
8	8	GND	Ground
9	9	B3	Inverting Receiver Input for Channel 3
10	10	A3	Noninverting Receiver Input for Channel 3
11	11	Y3	Receiver Channel 3 Output
12	—	$\overline{G}$	Receiver Enable. Pull $\overline{G}$ low to enable all receivers. When $\overline{G}$ = high and G = low, the device is in low-power shutdown mode.
—	12	EN34	Receiver Enable for Channels 3 and 4. Pull EN34 high to enable Channel 3 and 4 receivers. When EN12 = low and EN34 = low, the device is in low-power shutdown mode.
13	13	Y4	Receiver Channel 4 Output
14	14	A4	Noninverting Receiver Input for Channel 4
15	15	B4	Inverting Receiver Input for Channel 4
16	16	V_{CC}	Supply Input. Bypass V_{CC} to ground with a 0.1µF ceramic capacitor as close to the device as possible.

Function Tables

Table 1. MAX33076E Function Table

INPUT			OUTPUT	MODE
G	$\overline{G}$	($V_{A\_}$-$V_{B\_}$)	Y_	
1	X	≥ +200mV	1	On
1	X	≤ -200mV	0	On
1	X	Open, Short	1	On
X	0	≥ +200mV	1	On
X	0	≤ -200mV	0	On
X	0	Open, Short	1	On
0	1	X	High-Z	Shutdown

Table 2. MAX33078E Y1/Y2 Function Table

INPUT			OUTPUT	MODE
EN12	EN34	($V_{A1/A2}$-$V_{B1/B2}$)	Y1/Y2	
1	X	≥ +200mV	1	On
1	X	≤ -200mV	0	On
1	X	Open, Short	1	On
0	1	X	High-Z	Y1/Y2 are off Y3/Y4 are on
0	0	X	High-Z	Shutdown

Table 3. MAX33078E Y3/Y4 Function Table

INPUT			OUTPUT	MODE
EN12	EN34	($V_{A3/A4}$-$V_{B3/B4}$)	Y3/Y4	
X	1	≥ +200mV	1	On
X	1	≤ -200mV	0	On
X	1	Open, Short	1	On
1	0	X	High-Z	Y3/Y4 are off Y1/Y2 are on
0	0	X	High-Z	Shutdown

X = Don't care, High-Z = High Impedance

Detailed Description

The MAX33076E/MAX33078E are 20Mbps robust quad-channel RS-485/RS-422 receivers with extended ±25V input common-mode operating range (CMR), ±65V fault-tolerant inputs, and ±25kV ESD for harsh electrical environments. Both devices operate with a +3.3V to +5V supply rail.

These devices feature an extended ±25V CMR, which ensures that the MAX33076E/MAX33078E reliably receive data when the ground planes between two nodes have large differences or when interference may couple onto the bus from motors or other electrical noise sources. The ±65V fault-tolerant A and B inputs ensure the device is protected when data lines are shorted to external power supplies. The ±25kV ESD tolerance provides added protection on the receiver inputs from ESD strikes during production or in the field.

The MAX33076E/MAX33078E feature true fail-safe circuitry where the receiver output is set high when receiver inputs are open, shorted, or connected to a terminated transmission line with all drivers disabled. The receiver enable inputs (G and $\overline{G}$) on the MAX33076E enable or disable the outputs. The EN12 and EN34 pins on MAX33078E enable the Y1/Y2 and Y3/Y4 outputs, respectively.

Differential Input Thresholds

The MAX33076E/MAX33078E receive RS-485/RS-422 differential input signals on the A_ and B_ inputs and output a corresponding single-ended, logic-level signal on Y_. The RS-485 standard specifies the receiver output state to be logic high or 1 for differential input voltage of ($V_{A\_}$-$V_{B\_}$) ≥ +200mV and logic low or 0 for ($V_{A\_}$-$V_{B\_}$) ≤ -200mV. If the differential receiver input signal ($V_{A\_}$-$V_{B\_}$) is between ±200mV, the receiver output is not defined per the standard.

True Fail-Safe

The MAX33076E/MAX33078E feature true fail-safe circuitry to ensure a logic high on the output Y_ when the inputs A_ and B_ are shorted or open for longer than 10µs (typ). When the differential input voltage is at 0V for 10µs (typ), the Y_ output is logic high.

Transmission line termination is required for RS-485/RS-422 high-speed signals over long cables. In the case of a terminated bus with all drivers disabled, the differential input voltage is pulled to 0V by the termination resistor, and Y_ is guaranteed to be logic high after 10µs (typ).

Common-Mode Range

The MAX33076E/MAX33078E ±25V common-mode range exceeds the -7V to +12V required in the RS-485 standard. This extended common-mode range is optimized for systems where there is a large difference in ground potentials between nodes.

Low-Power Shutdown Mode

The MAX33076E enters low-power shutdown mode when G is low and $\overline{G}$ is high for at least 400ns (max). All outputs go high impedance in shutdown mode, and the device draws 400µA (typ) of supply current. To exit shutdown mode, set G to high or $\overline{G}$ to low. For applications using only a single enable signal, pull $\overline{G}$ low; see *Typical Application Diagram for MAX33076E*.

The MAX33078E enters low-power shutdown mode when EN12 and EN34 are pulled low for at least 400ns (max). All outputs go high impedance in shutdown mode, and the device draws 400µA (typ) of supply current. To exit shutdown mode, set EN12 or EN34 high.

Thermal Shutdown Protection

The MAX33076E/MAX33078E provide thermal shutdown circuitry to protect the device. All outputs are high impedance when the junction temperature exceeds +160°C (typ). The outputs are re-enabled when the junction temperature falls below +148°C (typ).

Fault-Tolerant Inputs (A_ and B_)

The receiver inputs of the MAX33076E/MAX33078E are designed to withstand voltages up to ±65V with respect to ground without damage. The inputs are capable of withstanding up to ±65V when the device is powered or unpowered.

Applications Information

The MAX33076E/MAX33078E high-speed quad RS-485/RS-422 receivers offer premium performance with a highly integrated, robust feature set of fault-tolerant inputs, extended common-mode range, and ESD protection.

Layout Guidelines

- Place a 0.1µF ceramic decoupling capacitor as close as possible to the V_{CC} pin.
- Separate the solid ground and power planes to minimize noise and ensure a low-impedance connection to these planes.
- Keep PCB traces as short as possible between the receiver and the connector to minimize attenuation and reflection.
- Place the termination resistors as close to the receiver as possible.
- For signal integrity, route the receiver inputs away from the supply lines.
- For a multipoint bus, keep stub length to a minimum to avoid reflections on the line.

Upgrading from MAX3093E/MAX3094E to MAX33078E

The MAX33078E is a cost-effective upgrade to the MAX3093E/MAX3094E. The MAX33078E features an extended ±25V common-mode input range and operates over a wide -40°C to +125°C operating temperature range. Additionally, the MAX33078E operates with a +3.3V to +5V supply rail up to 20Mbps.

With an SOIC package, the MAX33078E can be used as a drop-in replacement for the MAX3093E/MAX3094E with some functional differences. For example, the MAX33078E features a wide 200mV (typ) input hysteresis compared to 45mV (typ) on the MAX3093E/MAX3094E. However, the operating supply current for the MAX33078E is higher than the MAX3093E/MAX3094E.

Upgrading from MAX3095/MAX3096 to MAX33076E

The MAX33076E is pin-compatible with the MAX3095/MAX3096 with some functional differences. The MAX33076E features ±25kV ESD HBM (Human Body Model) protection with an extended ±25V common-mode input range and operates over a wide -40°C to +125°C temperature range. The device operates with a +3.3V to +5V supply rail. In addition, the MAX33076E operates up to 20Mbps and features a wide 200mV (typ) input hysteresis. The operating current of the MAX33076E is higher than the supply current of the MAX3095/MAX3096.

External Transient Protection

For applications requiring high-voltage transient protection, such as surge transients, external protections are needed on the bus lines. The MAX33076E/MAX33078E feature ±70V absolute maximum voltage ratings on the A_ and B_ inputs, allowing the use of higher clamping voltage TVS diodes for protection. External TVS diodes such as SM30T35CAY clamp the bus voltage below ±70V during ±2kV/80Ω per IEC 61000-4-5. Ensure the external protection added to the bus lines does not slew the signals at the required operating data rate.

ESD Protection

ESD protection structures are incorporated on all pins to protect against electrostatic discharge encountered during handling and assembly. The inputs (A_ and B_ data lines) of the MAX33076E/MAX33078E have extra protection against static electricity. The ESD structures withstand high ESD in normal operation and when powered down. After an ESD event, the devices keep working without latch-up or damage.

ESD protection can be tested in various ways. The receiver inputs (A_ and B_ data lines) of the devices are designed for protection to the following limits (referenced to ground):

- ±25kV Human Body Model (HBM)
- ±4kV using the Air Gap Discharge method specified in IEC 61000-4-2
- ±4kV using the Contact Discharge method specified in IEC 61000-4-2

To achieve higher IEC 61000-4-2 ESD levels, external protection circuity, such as TVS or MOV, are required on the bus lines.

Human Body Model (HBM)

Figure 3 shows the HBM test model, and *Figure 4* shows the current waveform that is generated when discharged in a low-impedance state. This model consists of a 100pF capacitor charged to the ESD voltage of interest, which is then discharged into the test device through a 1.5kΩ resistor.

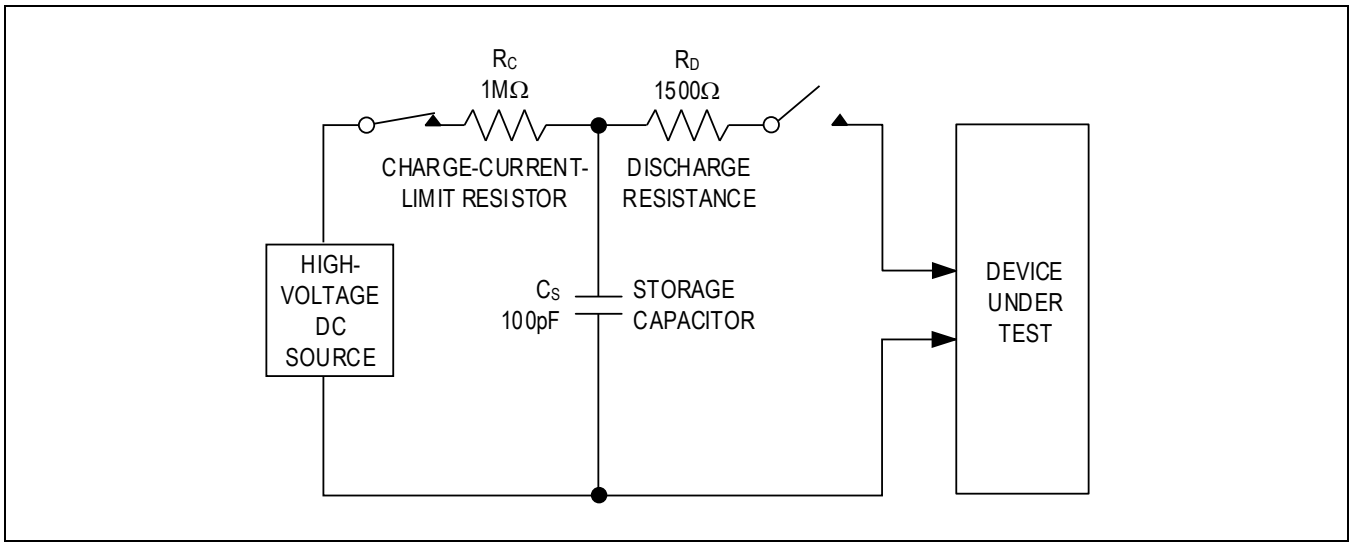


Figure 3. Human Body ESD Test Model

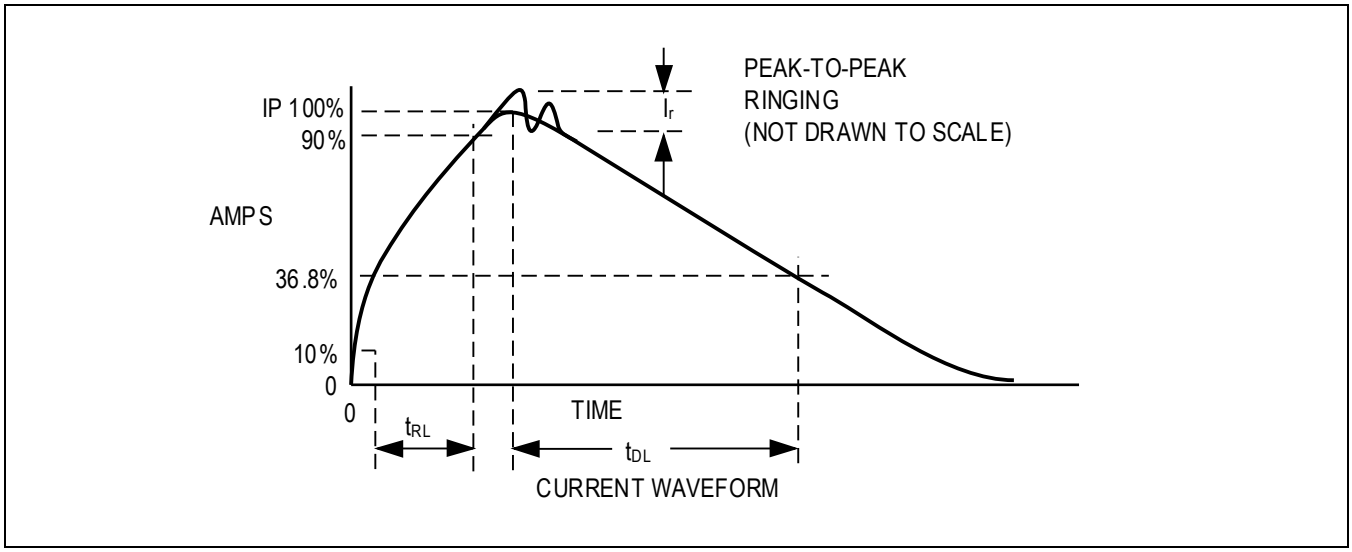


Figure 4. Human Body Current Waveform

IEC 61000-4-2

The IEC 61000-4-2 standard covers ESD testing and performance of finished equipment. However, it does not specifically refer to integrated circuits. The MAX33076E/MAX33078E help in designing equipment to meet IEC 61000-4-2. The major difference between tests done using the HBM and IEC 61000-4-2 is higher peak current in IEC 61000-4-2 because series resistance is lower in the IEC 61000-4-2 model. Hence, the ESD withstand voltage measured to IEC 61000-4-2 is generally lower than that measured using the HBM. *Figure 5* shows the IEC 61000-4-2 test model, and *Figure 6* shows the current waveform for IEC 61000-4-2 ESD Contact Discharge and Air Gap tests.

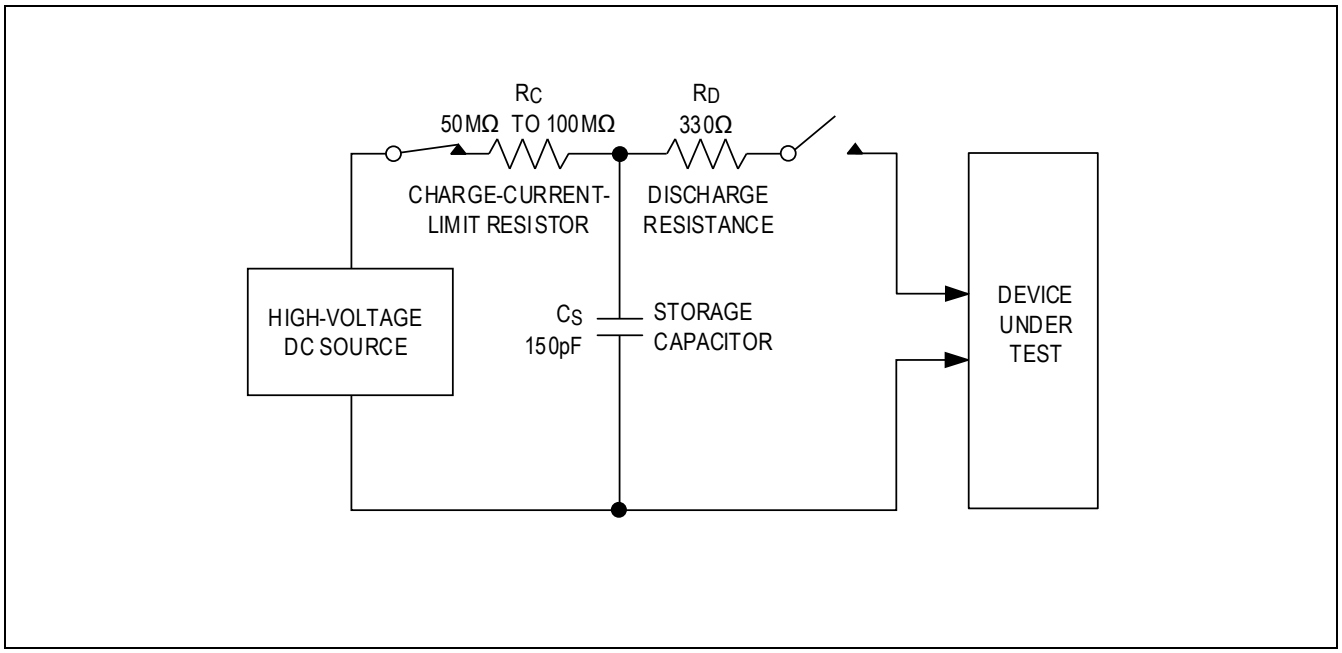


Figure 5. IEC 61000-4-2 ESD Test Model

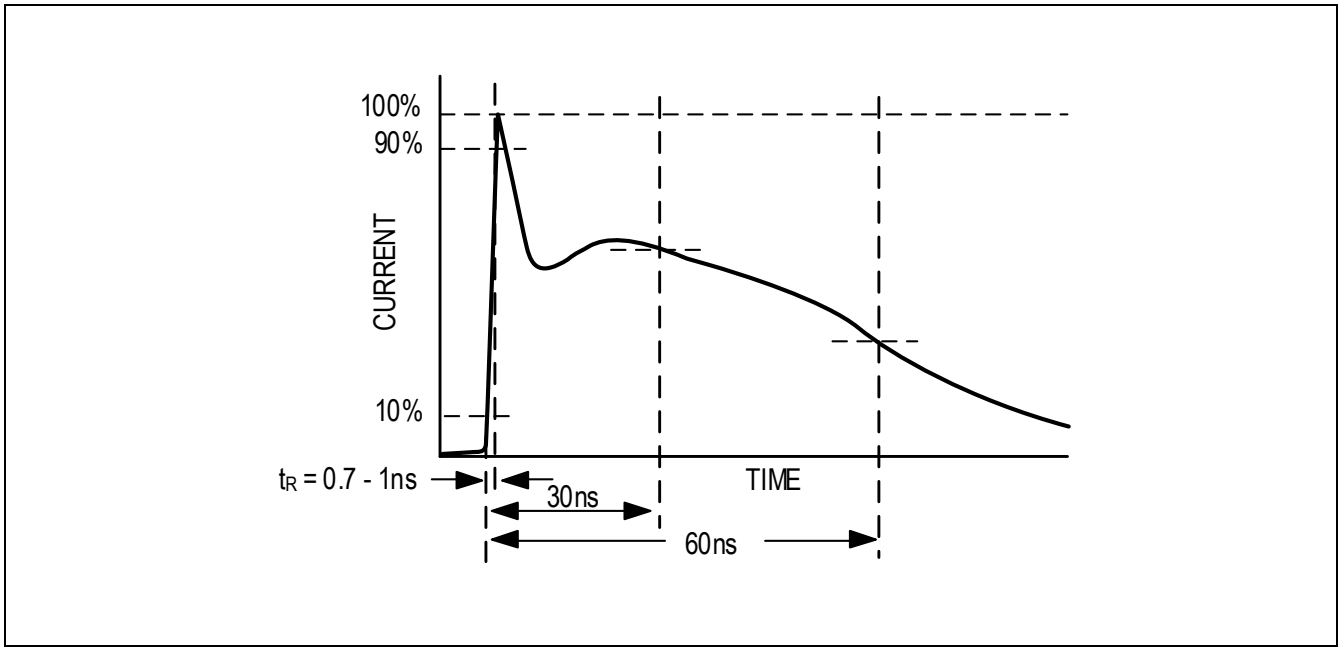
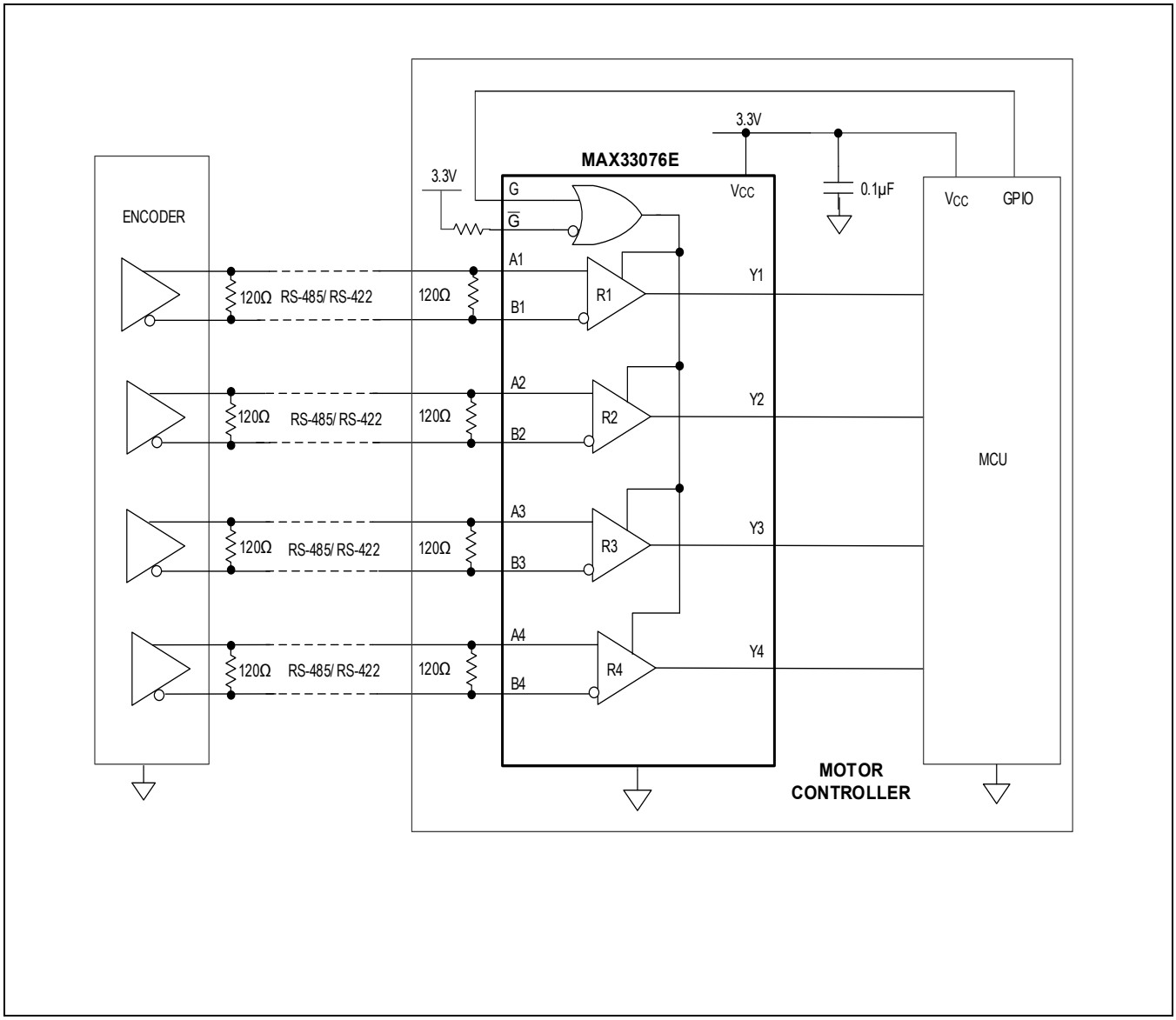


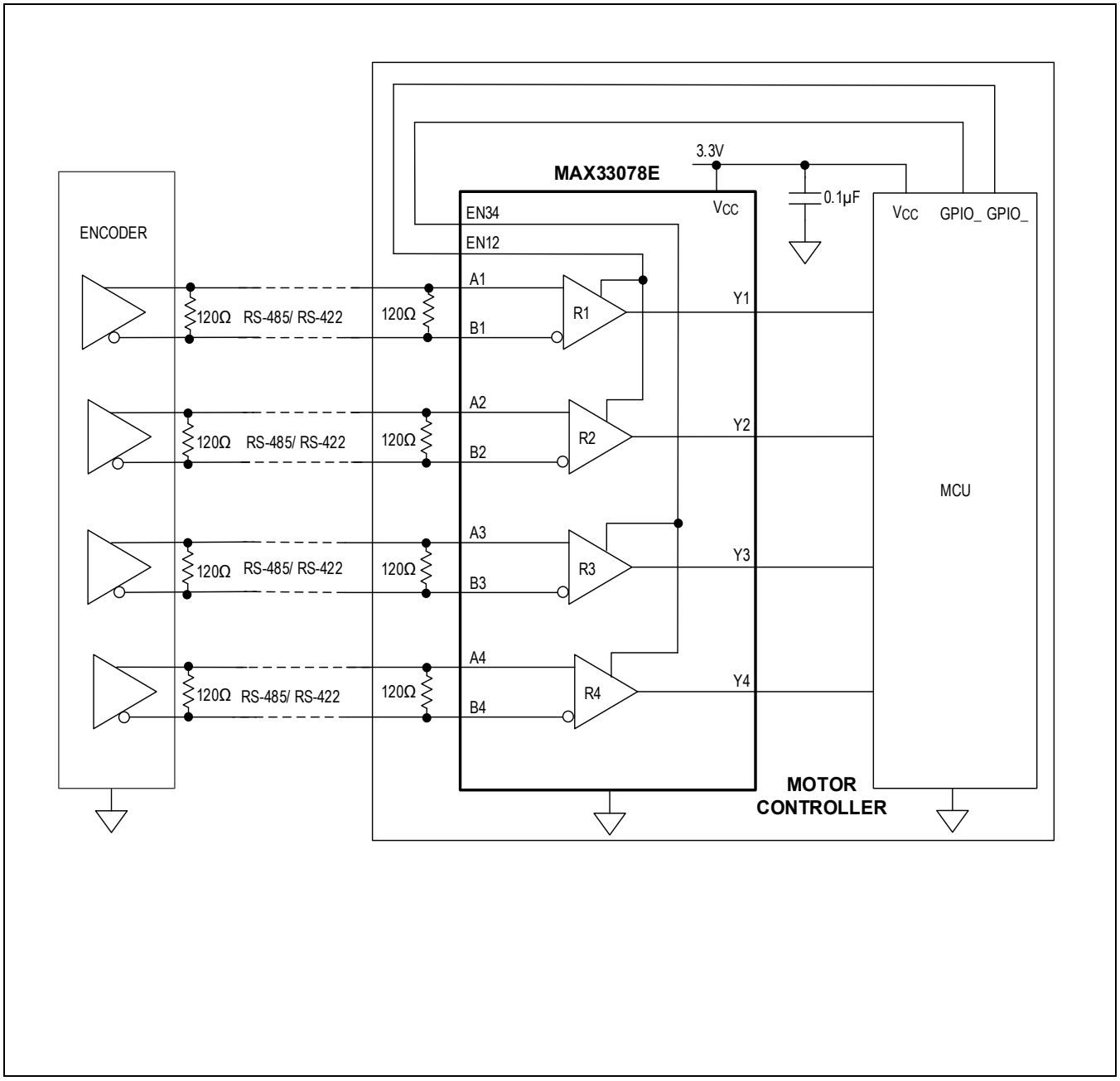
Figure 6. IEC 61000-4-2 ESD Generator Current Waveform

Typical Application Circuits

Typical Application Diagram for MAX33076E



Typical Application Diagram for MAX33078E



Ordering Information

PART NUMBER	TEMP RANGE	PIN-PACKAGE	ENABLE
MAX33076EAEE+	-40°C to +125°C	16 QSOP	G, $\overline{G}$
MAX33076EAEE+T	-40°C to +125°C	16 QSOP	G, $\overline{G}$
MAX33076EASE+	-40°C to +125°C	16 SOIC	G, $\overline{G}$
MAX33076EASE+T	-40°C to +125°C	16 SOIC	G, $\overline{G}$
MAX33078EAEE+	-40°C to +125°C	16 QSOP	EN12, EN34
MAX33078EAEE+T	-40°C to +125°C	16 QSOP	EN12, EN34
MAX33078EASE+	-40°C to +125°C	16 SOIC	EN12, EN34
MAX33078EASE+T	-40°C to +125°C	16 SOIC	EN12, EN34

+Denotes a lead (Pb)-free/RoHS-compliant package.
T = Tape and reel.

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	2/22	Release for Market Intro	—
1	7/24	Added new release information. Removed MAX33077E and MAX33079E part numbers. Updated General Description, Applications, Benefits and Features, Simplified Block Diagram, Absolute Maximum Ratings, Package Information, Electrical Characteristics, Test Circuits and Timing Diagrams, Typical Operating Characteristics, Pin Configurations, Pin Descriptions, Function Table, Detailed Description, Applications Information, Typical Application Circuits, and Ordering Information.	1-17

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