



General Description

The MAX6969 serial-interfaced LED driver provides 16 open-drain, constant-current-sinking LED driver outputs rated at 5.5V. The MAX6969 operates from a 3V to 5.5V supply. The MAX6969 supply and the LEDs' supply or supplies can power up in any order. The constant-current outputs are programmed together to up to 55mA using a single external resistor. The MAX6969 operates with a 25Mb, industry-standard, 4-wire serial interface.

The MAX6969 uses the industry-standard, shift-register-plus-latch-type serial interface. The driver accepts data shifted into a 16-bit shift register using data input DIN and clock input CLK. Input data appears at the DOUT output 16 clock cycles later to allow cascading of multiple MAX6969s. The latch-enable input, LE, loads the 16 bits of shift register data into a 16-bit output latch to set which LEDs are on and which are off. The output-enable, $\overline{\rm OE}$, gates all 16 outputs on and off, and is fast enough to be used as a PWM input for LED intensity control.

For applications requiring LED fault detection, refer to the MAX6984*, which automatically detects open-circuit LEDs.

For safety-related applications requiring a watchdog timer, refer to the MAX6979, which includes a fail-safe feature that blanks the display if the serial interface becomes inactive for more than 1s.

The MAX6969 is one of a family of 12 shift-register-plus-latch-type LED drivers. The family includes 8-port and 16-port types, with 5.5V- or 36V-rated LED outputs, with and without open-circuit LED detection and watchdog. All versions operate from a 3V to 5.5V supply, and are specified over the -40°C to +125°C temperature range.

_Applications

Variable Message Signs

Marquee Displays

Point-of-Order Signs

Traffic Signs

Gaming Features

Architectural Lighting

*Future product—contact factory for availability.

Features

- ◆ 25Mb, Industry-Standard, 4-Wire Serial Interface at 5V
- ♦ 3V to 5.5V Logic Supply
- ♦ 16 Constant-Current LED Outputs Rated at 5.5V
- ♦ Up to 55mA Continuous Current per Output
- ♦ Output Current Programmed by Single Resistor
- ♦ 3% Current Matching Between Outputs
- ♦ 6% Current Matching Between ICs
- ♦ High-Dissipation, 24-Pin Packages
- ♦ -40°C to +125°C Temperature Range

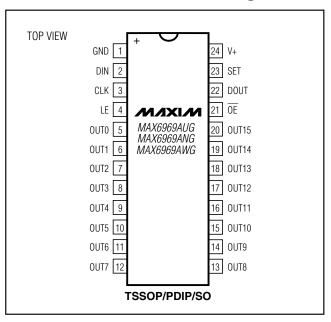
Ordering Information

PART	TEMP RANGE	PIN-PACKAGE				
MAX6969AUG+	-40°C to +125°C	24 TSSOP				
MAX6969AWG+	-40°C to +125°C	24 Wide SO				
MAX6969ANG+	-40°C to +125°C	24 PDIP				

⁺Denotes a lead(Pb)-free/RoHS-compliant package.

Typical Application Circuit and Selector Guide appear at end of data sheet.

Pin Configuration



ABSOLUTE MAXIMUM RATINGS

Voltage with respect to GND.	
V+	
OUT	0.3V to +6V
DIN, CLK, LE, OE, SET	0.3V to $(V + + 0.3V)$
DOUT Current	
OUT_ Sink Current	60mA
Total GND Current	

Continuous Power Dissipation (T _A = +70°C)	
24-Pin TSSOP (derate 12.2mW/°C over +70°C)	975mW
24-Pin PDIP (derate 13.3mW/°C over +70°C)	1067mW
24 Wide SO (derate 11.8mW/°C over +70°C)	941mW
Operating Temperature Range40°	°C to +125°C
Junction Temperature	+150°C
Storage Temperature Range65°	°C to +150°C
Lead Temperature (soldering, 10s)	+300°C
Soldering Temperature (reflow)	+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.

ELECTRICAL CHARACTERISTICS

(Typical Application Circuit, V+=3V to 5.5V, $T_A=T_{MIN}$ to T_{MAX} , unless otherwise noted. Typical values are at V+=5V, $T_A=+25^{\circ}C$.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Supply Voltage	V+		3.0		5.5	V
Output Voltage	Vout				5.5	V
Standby Current (Interface Idle, All Output Ports High Impedance, $R_{SET} = 360\Omega$)	I ₊	All logic inputs at V+ or GND, DOUT unloaded		5.7	8	mA
Standby Current (Interface Running, All Output Ports High Impedance, $R_{SET} = 360\Omega$)	l ₊	$f_{CLK} = 5MHz$, $\overline{OE} = V+$, DIN and LE = V+ or GND, DOUT unloaded		6	8.5	mA
Supply Current (Interface Idle, All Output Ports Active Low, $R_{SET} = 360\Omega$)	l ₊	All logic inputs at V+ or GND, DOUT unloaded		18	25	mA
Input High Voltage DIN, CLK, LE, OE	V _{IH}		0.7 x V+			V
Input Low Voltage DIN, CLK, LE, OE	V _{IL}				0.3 x V+	V
Hysteresis Voltage DIN, CLK, LE, OE	ΔVI			0.8		V
Input Leakage Current DIN, CLK, LE, OE	I _{IH} , I _{IL}		-1		+1	μΑ
Output High-Voltage DOUT	Voн	ISOURCE = 4mA	V+ - 0.5V			V
Output Low Voltage	Vol	I _{SINK} = 4mA			0.5	V
Output Current OUT_	lout	$V+=3V$ to 5.5V, $V_{OUT}=0.5V$ to 2.5V, $R_{SET}=360\Omega$	37	50	61	mA
Output Leakage Current OUT_	ILEAK	OE = V+, OUT_ = V+			1	μΑ

5V TIMING CHARACTERISTICS

(Typical Application Circuit, V+ = 4.5V to 5.5V, $T_A = T_{MIN}$ to T_{MAX} , unless otherwise noted.) (Notes 1, 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
CLK Clock Period	tcp		40			ns
CLK Pulse-Width High	tсн		19			ns
CLK Pulse-Width Low	tCL		19			ns
DIN Setup Time	tDS		4			ns
DIN Hold Time	tDH		8			ns
DOUT Propagation Delay	t _{DO}		12		32	ns
DOUT Rise and Fall Time	t _{DR} , t _{DF}	C _{DOUT} = 10pF, 20% to 80%			10	ns
LE Pulse-Width High	t _{LW}		20			ns
LE Setup Time	tLS		10			ns
LE Rising to OUT_ Rising Delay	tLRR				100	ns
LE Rising to OUT_ Falling Delay	tLRF				300	ns
CLK Rising to OUT_ Rising Delay	tcrr				100	ns
CLK Rising to OUT_ Falling Delay	tCRF				310	ns
OE Rising to OUT_ Rising Delay	t oe h				100	ns
OE Falling to OUT_ Falling Delay	toel				320	ns
LED Output OUT_ Turn-On Fall Time	t _f	80% to 20%, pullup resistor = 65Ω			120	ns
LED Output OUT_ Turn-Off Rise Time	t _r	20% to 80%, pullup resistor = 65Ω			120	ns

3.3V TIMING CHARACTERISTICS

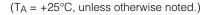
(Typical Application Circuit, V+=3V to 5.5V, $T_A=T_{MIN}$ to T_{MAX} , unless otherwise noted.) (Notes 1, 2)

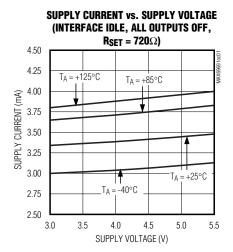
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
CLK Clock Period	tCP		52			ns
CLK Pulse-Width High	tсн		24			ns
CLK Pulse-Width Low	tCL		24			ns
DIN Setup Time	t _{DS}		4			ns
DIN Hold Time	tDH		8			ns
DOUT Propagation Delay	t _{DO}		12		50	ns
DOUT Rise and Fall Time	t _{DR} , t _{DF}	C _{DOUT} = 10pF, 20% to 80%			12	ns
LE Pulse-Width High	tLW		20			ns
LE Setup Time	tLS		15			ns
LE Rising to OUT_ Rising Delay	tLRR				120	ns
LE Rising to OUT_ Falling Delay	tLRF				310	ns
CLK Rising to OUT_ Rising Delay	tcrr				120	ns
CLK Rising to OUT_ Falling Delay	tCRF				330	ns
OE Rising to OUT_ Rising Delay	t oe h				120	ns
OE Falling to OUT_ Falling Delay	t oe l				330	ns
LED Output OUT_ Turn-On Fall Time	tf	80% to 20%, pullup resistor = 65Ω			120	ns
LED Output OUT_ Turn-Off Rise Time	t _r	20% to 80%, pullup resistor = 65Ω			120	ns

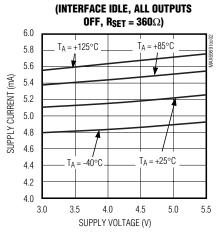
Note 1: All parameters tested at $T_A = +25$ °C. Specifications over temperature are guaranteed by design.

Note 2: See Figure 3.

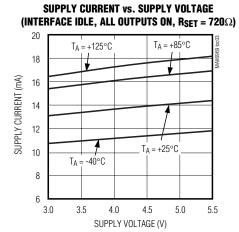
Typical Operating Characteristics







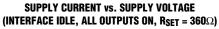
SUPPLY CURRENT vs. SUPPLY VOLTAGE

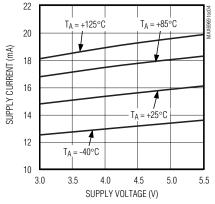


MIXIM

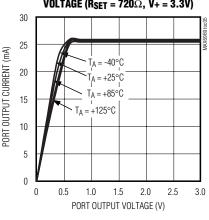
Typical Operating Characteristics (continued)

 $(T_A = +25^{\circ}C, \text{ unless otherwise noted.})$

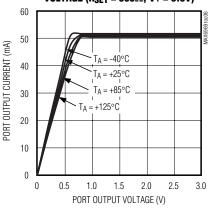


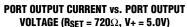


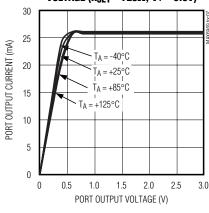
PORT OUTPUT CURRENT vs. PORT OUTPUT VOLTAGE ($R_{SET} = 720\Omega$, V+ = 3.3V)



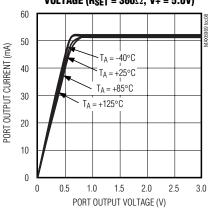
PORT OUTPUT CURRENT vs. PORT OUTPUT VOLTAGE ($R_{SET} = 360\Omega$, V+ = 3.3V)



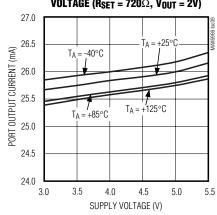


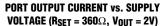


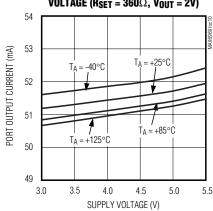
PORT OUTPUT CURRENT vs. PORT OUTPUT VOLTAGE (R_{SET} = 360 Ω , V+ = 5.0V)



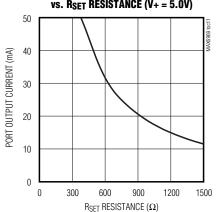
PORT OUTPUT CURRENT vs. SUPPLY VOLTAGE ($R_{SET} = 720\Omega$, $V_{OUT} = 2V$)







PORT OUTPUT CURRENT vs. R_{SET} RESISTANCE (V+ = 5.0V)



Pin Description

PIN	NAME	FUNCTION
1	GND	Ground
2	DIN	Serial-Data Input. Data is loaded into the internal 16-bit shift register on CLK's rising edge.
3	CLK	Serial-Clock Input. Data is loaded into the internal 16-bit shift register on CLK's rising edge.
4	LE	Load-Enable Input. Data is loaded transparently from the internal shift register(s) to the output latch(es) while LE is high. Data is latched into the output latch(es) on LE's falling edge, and retained while LE is low.
5–20	OUT0-OUT15	LED Driver Outputs. OUT0 to OUT15 are open-drain, constant-current-sinking outputs rated to 5.5V.
21	ŌĒ	Output-Enable Input. High forces outputs OUT0 to OUT15 high impedance, without altering the contents of the output latches. Low enables outputs OUT0 to OUT15 to follow the state of the output latches.
22	DOUT	Serial-Data Output. Data is clocked out of the 16-bit internal shift register to DOUT on CLK's rising edge.
23	SET	LED Current Setting. Connect SET to GND through a resistor (R _{SET}) to set the maximum LED current.
24	V+	Positive Supply Voltage. Bypass V+ to GND with a 0.1µF ceramic capacitor.

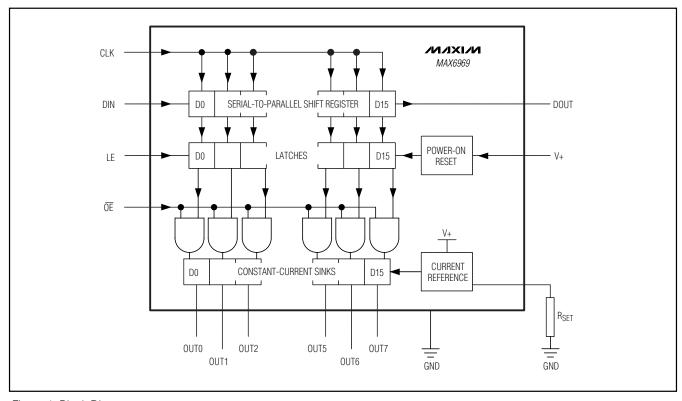


Figure 1. Block Diagram

Detailed Description

The MAX6969 LED driver comprises a 4-wire serial interface driving 16 constant-current-sinking, opendrain output ports. The outputs drive LEDs in either static or multiplex applications (Figure 1). The constant-current outputs are guaranteed for current accuracy not only with chip-supply voltage variations (5V $\pm 10\%$ and 3V to 5.5V), but also over a realistic range of driver output voltage drop (0.5V to 2.5V). The drivers use current-sensing feedback circuitry (not simple current mirrors) to ensure very small current variations over the full allowed range of output voltage (see the *Typical Operating Characteristics*).

The 4-wire serial interface comprises a 16-bit shift register and a 16-bit transparent latch. The shift register is written through a clock input, CLK, and a data input, DIN, and the data propagates to a data output, DOUT. The data output allows multiple drivers to be cascaded and operated together. The contents of the 16-bit shift register are loaded into the transparent latch through a latch-enable input, LE. The latch is transparent to the shift register outputs when high, and latches the current state on the falling edge of LE.

Each driver output is an open-drain, constant-current sink that should be connected to the cathode of either a single LED or a series string of multiple LEDs. The LED anode can be connected to a supply voltage of up to 5.5V, independent of the MAX6969 supply, V+. The constant-current capability is up to 55mA per output, set for all eight outputs by an external resistor, RSET.

Initial Power-Up and Operation

An internal reset circuit clears the internal registers of the MAX6969 on power-up. All outputs (OUT0-OUT15) initialize to high impedance, regardless of the initial logic levels of the CLK, DIN, \overline{OE} , and LE inputs.

4-Wire Serial Interface

The serial interface on the MAX6969 is a 4-wire serial interface using four inputs (DIN, CLK, LE, \overline{OE}) and a data output (DOUT). This interface is used to write display data to the MAX6969. The serial-interface data word length is 16 bits, D0–D15. See Figure 2.

The functions of the five interface pins are as follows. DIN is the serial-data input, and must be stable when it is sampled on the rising edge of CLK. Data is shifted in, MSB first. This means that data bit D15 is clocked in first, followed by 15 more data bits finishing with the LSB, D0.

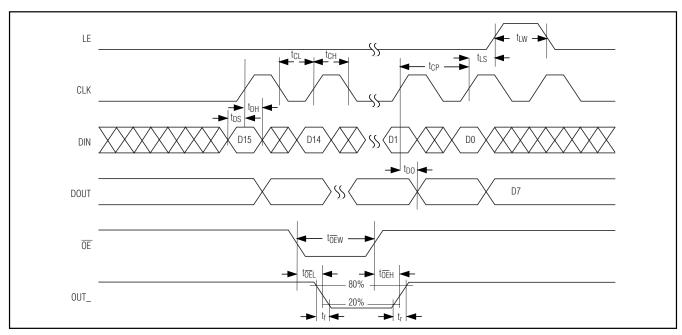


Figure 2. 4-Wire Serial-Interface Timing Diagram

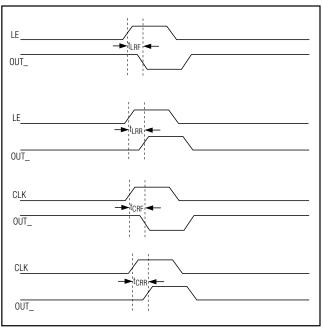


Figure 3. LE and CLK to OUT_ Timing

CLK is the serial-clock input, which shifts data at DIN into the MAX6969 16-bit shift register on its rising edge.

LE is the latch load input of the MAX6969 that transfers data from the MAX6969 16-bit shift register to its 16-bit latch when LE is high (transparent latch), and latches the data on the falling edge of LE (Figure 2).

The fourth input provides output-enable control of the output drivers. \overline{OE} is high to force outputs OUT0-OUT15 high impedance, without altering the contents of the output latches, and low to enable outputs OUT0-OUT15 to follow the state of the output latches.

 $\overline{\text{OE}}$ is independent of the operation of the serial interface. Data can be shifted into the serial-interface shift register and latched, regardless of the state of $\overline{\text{OE}}$.

DOUT is the serial-data output, which shifts data out from the MAX6969's 16-bit shift register on the rising edge of CLK. Data at DIN is propagated through the shift register and appears at DOUT 16 clock cycles later.

Table 1. 4-Wire Serial-Interface Truth Table

SERIAL DATA	CLOCK		_	FT-RI				LOAD		LATO	сн сс	ONTE	NTS		BLANKING INPUT	OUTPUT CONTENTS						
INPUT DIN	CLK	D ₀	D ₁	D ₂		D _{n-1}	Dn	LE	D ₀	D ₁	D ₂		D _{n-1}	Dn	OE	D ₀	D ₁	D ₂		D _{n-1}	Dn	
Н	7	Н	R ₀	R ₁		R _{n-2}	R _{n-1}	_	_	_	_	_	_	_	_	_	_	_	_	_	_	
L	 	L	R ₀	R ₁		R _{n-2}	R _{n-1}	_		_					_	_	_		_	_	_	
Х	一	R ₀	R ₁	R ₂		R _{n-1}	Rn	_		_			_		_	_	_		_	_	_	
_		Χ	Χ	Χ		Χ	Χ	L	R ₀	R ₁	R ₂		R _{n-1}	Rn	_	_	_		_			
	_	P ₀	P ₁	P ₂		P _{n-1}	Pn	Н	P ₀	P ₁	P ₂		P _{n-1}	Pn	L	P ₀	P ₁	P ₂		P _{n-1}	Pn	
_	_	_		_	_	_	_	_	Χ	Χ	Χ		Χ	Χ	Н	Hi-Z	Hi-Z	Hi-Z		Hi-Z	Hi-Z	

L = Low-logic level.

H = High-logic level.

X = Don't care.

P = Present state.

R = Previous state.

Hi-Z = High impedance.

Applications Information

Selecting External Component RSET to Set LED Output Current

The MAX6969 uses an external resistor, RSET, to set the LED current for outputs OUT0–OUT15. The minimum allowed value of RSET is 327.3 Ω , which sets the output currents to 55mA. The maximum allowed value of RSET is 1.5k Ω . The reference value, 360 Ω , sets the output currents to 50mA. To set a different output current, use the formula:

RSET = 18,000 / IOUT

where IOUT is the desired output current in mA.

Computing Power Dissipation

The upper limit for power dissipation (PD) for the MAX6969 is determined by the following equation:

$$P_D = (V + x I +) + (V_{OUT} \times DUTY \times I_{OUT} \times N)$$

where:

V+ = supply voltage

I+= operating supply current when sinking I_{OUT} LED drive current into N outputs

DUTY = PWM duty cycle applied to OE

N = number of MAX6969 outputs driving LEDs at the same time (maximum is 16)

Vout = MAX6969 port output voltage when driving load LED(s)

IOUT = LED drive current programmed by RSFT

P_D = power dissipation, in mW if currents are in mA Dissipation example:

$$I_{OUT} = 47mA$$
, $N = 16$, $DUTY = 1$, $V_{OUT} = 2V$, $V_{+} = 5.25V$

 $P_D = (5.25V \times 50mA) + (2V \times 1 \times 47mA \times 16) = 1.767W$

Thus, for a 24-pin TSSOP package ($T_{JA} = 1 / 0.0122 = +82^{\circ}C/W$ from the *Absolute Maximum Ratings*), the maximum allowed ambient temperature T_{A} is given by:

$$T_{J(MAX)} = T_A + (P_D \times T_{JA}) = +150^{\circ}C = T_A + (1.767 \times 82^{\circ}C/W)$$

so $T_A = +145.6$ °C.

Overtemperature Cutoff

The MAX6969 contains an internal temperature sensor that turns off all outputs when the die temperature exceeds approximately +165°C. The outputs are enabled again when the die temperature drops below approximately +140°C. Register contents are not affected, so when a driver is overdissipating, the external symptom is the load LEDs cycling between on and off as the driver repeatedly overheats and cools, alternately turning the LEDs off and then back on again.

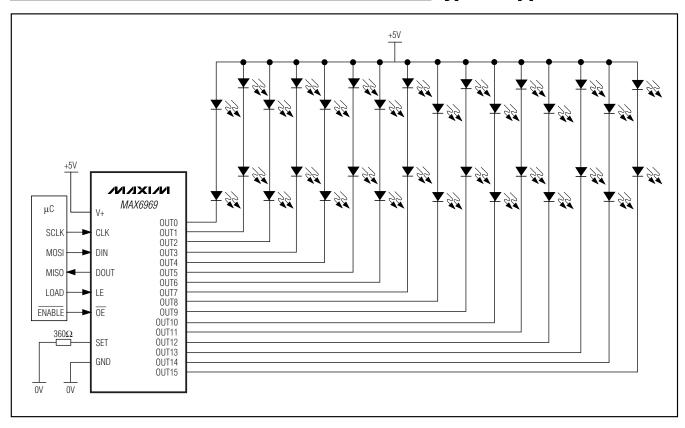
Power-Supply Considerations

The MAX6969 operates with a chip supply V+, and one or more LED supplies. Bypass each supply to GND with a 0.1µF capacitor as close to the MAX6969 as possible. This is normally adequate for static LED driving. For multiplex or PWM applications, it is necessary to add an additional bulk electrolytic capacitor of 4.7µF or more to each supply for every 4 to 16 MAX6969s. The necessary capacitance depends on the LED load current, PWM switching frequency, and serial-interface speed. Inadequate V+ decoupling can cause timing problems, and very noisy LED supplies can affect LED current regulation.

Selector Guide

PART	NO. OF OUTPUTS	MAX OUTPUT VOLTAGE (V)	MAX OUTPUT CURRENT	LED FAULT DETECTION	WATCHDOG
MAX6968				_	_
MAX6977	8	5.5		Yes	_
MAX6978				Yes	Yes
MAX6970	8			_	_
MAX6981		36	36	Yes	_
MAX6980			55mA	Yes	Yes
MAX6969		16 5.5		_	_
MAX6984	16			Yes	_
MAX6979				Yes	Yes
MAX6971				_	_
MAX6982	16	36		Yes	_
MAX6983				Yes	Yes

Typical Application Circuit



_____Chip Information

PROCESS: BiCMOS

Package Information

For the latest package outline information and land patterns, go to www.maxim-ic.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	DOCUMENT NO.
24 PDIP	N24+1	<u>21-0043</u>
24 TSSOP	U24+1	<u>21-0066</u>
24 Wide SO	W24+1	21-0042



Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
3	6/10	Updated Ordering Information, Absolute Maximum Ratings, Electrical Characteristics, and Table 1	1, 2, 8

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