16-bit Constant-Current LED Driver with Modeless™ Error Detection

Product Description

The SCT2027 is a serial-interfaced 16-bit constant-current sinker with error detection designed for LED displays and LED lighting applications. In applications, an external resistor is used to adjust the full-scale output current from 5mA up to 90mA. The serial data are shifted into 16-bit shift register by clock signal. Input data appear at the SDO output 16 clock cycles later to allow cascading of multiple SCT2027s. The latch-enable input, LA/, loads the 16 bits data of shift register into a 16-bit latch to determine which LEDs are on and off. The output enable input, OE/ gates all 16 outputs on and off, and is fast enough to be used as PWM input for the LED intensity control.

The SCT2027 combines the SCT2024/6 with Modeless™ technique to detect open-load and shorted-load errors while driving the LEDs without mode switching*. With the pin-to-pin compatible design, all the LED display or lighting systems can be upgraded to perform the on-the-fly error-detection functions simply by replacing all the SCT2024/6s with SCT2027s directly. Also, by the Modeless™ technique, the software and hardware works well without reworks between systems of the SCT2024/6 and SCT2027.

During operations, the SCT2027 takes only 200ns to generate error status codes after the rising edge of LA/. The error status codes saved in the shift register can be shifted out via SDO bit-by-bit along with CLK, at the same time the new serial data can be shifted into SCT2027 via SDI. By comparing the display data with error status codes, the system control unit can read the error status to determine whether or not the LEDs are properly lit. If the input display signals are inconsistent with the corresponding output status code, the corresponding LEDs are determined to have been stuck open or short.

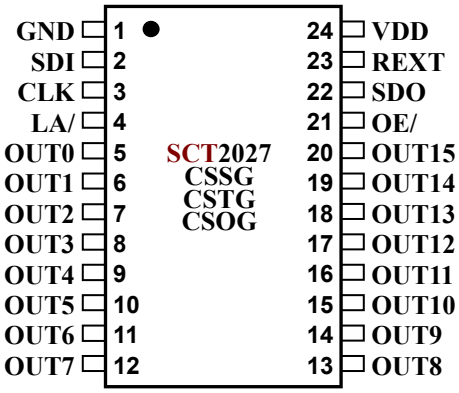
Since the high clock frequency can reach up to 25MHz, the SCT2027 satisfies the system requirements of high volume data transmission to control the LED display. The SCT2027 also guarantees each output endures up to 7V voltage stress, thus each output can drive multiple LEDs. The Modeless™ SCT2027 combines the error detection mechanism with display signals; hence the control unit does not need to switch between different modes, and therefore both the hardware costs and the control complexity can be reduced. In addition, the LED error status codes can be read in real time, and hence the fault status of the faulty LEDs can be discovered sooner.

*Starchips' patent protection.

Features

- Modeless™ On-the-fly error detection:
  Directly Data-In Error-Out, without mode shifting and command configuration
- Seamless backward compatible with SCT2024, SCT2026, SCT2210:
  Pin-to-pin package replacement without any PCB change
  Timing control the same as standard Serial-In Parallel-Out interface
- Concurrent open/short detection without selection
- Shorter 200ns error detection time
- 16 robust constant current sinker with LED power-supply voltage up to 7V
- Constant output current : 3 – 50/90mA@3.3/5V
- Wide power supply voltages: 3.3V to 5V
- Excellent regulation to load, supply voltage and temperature
  Temperature regulation: ±0.005%/°C,
  Load regulation: ±0.1%/V
  Line regulation: ±0.5%/V
- High current matching accuracy: ±1% between outputs, ±2% between ICs
- Fine grayscale response with 120ns PWM pulse width
- Dropout voltage 0.6V@60mA, V_{DD}=5V
- CMOS Schmitt trigger inputs with clock rate up to 25MHz @ cascade connection
- The constant current value of 16 outputs is set by a single external resistor
- Gradually 1.2ns delay of output, preventing instant current surge and output bouncing overstress
- Built-in power on reset(POR) circuit forces all the outputs off while power on
- Package: SSOP24, SSOP24-1, SOP24
- Applications: LED Traffic Signs, LED Displays, Variable Message Signs, Illumination

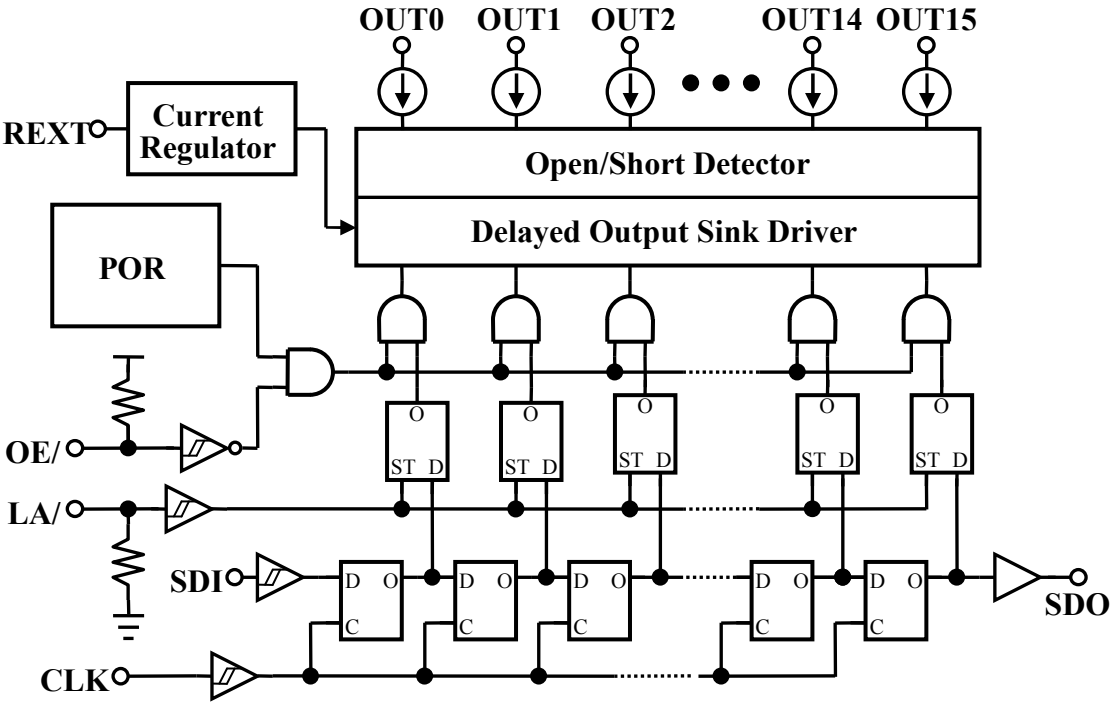
Pin Configurations



Terminal Description

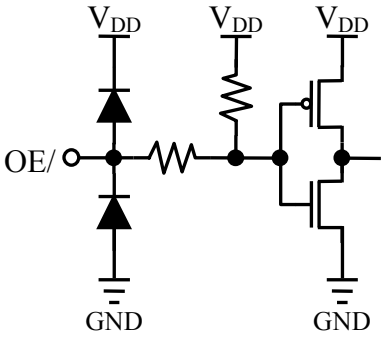
Pin Name	Pin No.	I/O	Function
GND	1	-	Ground terminal(thermal pad included)
SDI	2	I	Serial input of data shift register.
CLK	3	I	Clock input of shift register, data is sampled at the rising edge of CLK.
LA/	4	I	Input terminal of data strobe. Data is latched when LA/ is low. Error detection is executed on rising edge of LA/
OUT[0:15]	5-20	O	Open-drain, constant-current outputs.
OE/	21	I	Output enable signal. Output is enabled when OE/ is forced to low.
SDO	22	O	Output terminal of serial-data output to the SDI of next SCT2027. Error code is read out at next data frame.
REXT	23	I/O	Used to connect an external resistor for setting up all output current
VDD	24	-	Supply voltage terminal

Block Diagram

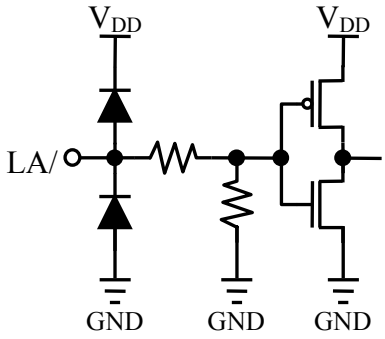


SCT2027

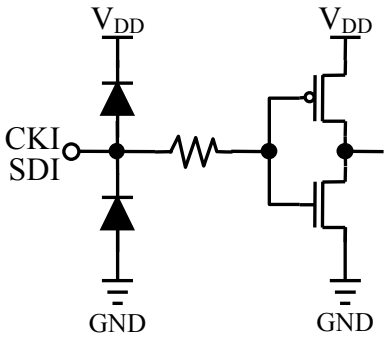
Equivalent Circuits of Inputs (1)



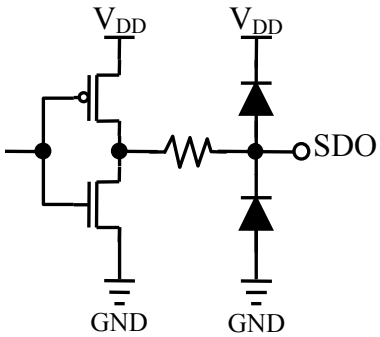
Equivalent Circuits of Inputs (2)



Equivalent Circuits of Inputs (3)



Equivalent Circuits of Output



Selector Guide

Part	Number of Outputs	Max Output Current (mA)	Min PWM Pulse Width (ns)	Supply Voltage (V)	Error Detection
SCT2110	8	180	100	5	NA
SCT2168	8	120	120	3.3/5	NA
SCT2169	8	120	120	3.3/5	Yes
SCT2167	8	60	180	3.3/5	NA
SCT2210	16	120	50	5	NA
SCT2026	16	90	120	3.3/5	NA
SCT2027	16	90	120	3.3/5	Yes
SCT2024	16	60	180	3.3/5	NA

Ordering Information

Part	Marking	Package	Unit per reel(pcs)
SCT2027CSSG	SCT2027CSSG	Green SSOP24	2500
SCT2027CSTG	SCT2027CSTG	Green SSOP24-1	2000
SCT2027CSOG	SCT2027CSOG	Green SOP24	1000

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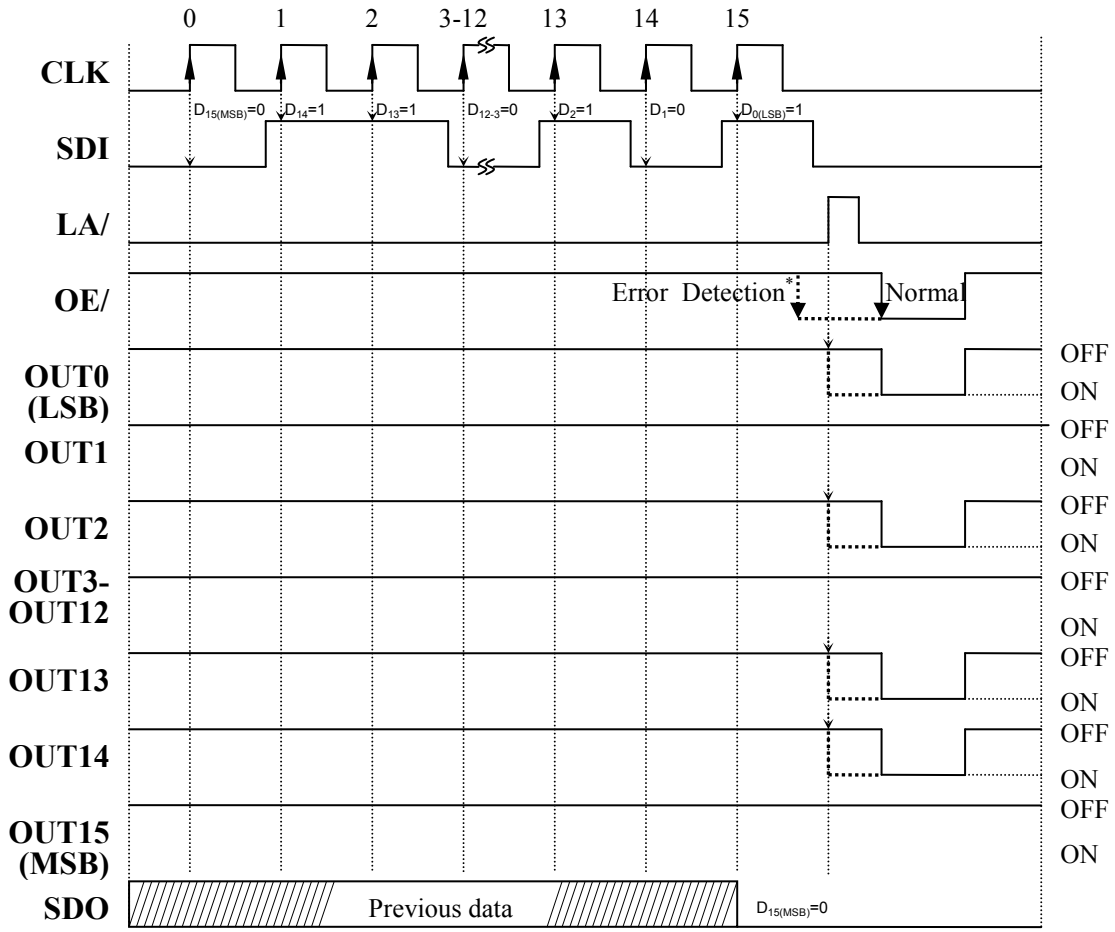
Timing Diagram



*Note: The OE/ signal should be active before error checking.

Maximum Ratings (T_A = 25°C)

Characteristic		Symbol	Rating	Unit
Supply voltage		V_{DD}	7.0	V
Input voltage		V_{IN}	-0.2 ~ V_{DD}+0.2	V
Output current		I_{OUT}	90	mA/Channel
Output voltage	SDO	V_{OUT}	-0.2 ~ V_{DD}+0.2	V
	OUT0~OUT15		-0.2 ~ 7	V
Total GND terminals current		I_{GND}	1200	mA
Power dissipation	SOP24	P_D	1.92	W
	SSOP24		1.42	
	SSOP24-1.0		1.74	
Thermal resistance	SOP24	$R_{TH(j-a)}$	65	°C /W
	SSOP24		88	
	SSOP24-1.0		72	
Operating junction temperature		$T_{J(max)}$	150	°C
Operating temperature		T_{OPR}	-40~+85	°C
Storage temperature		T_{STG}	-55~+150	°C

The absolute maximum ratings are a set of ratings not to be exceeded. Stresses beyond those listed under "Maximum Ratings" may cause the device breakdown, deterioration even permanent damage. Exposure to the maximum rating conditions for extended periods may affect device reliability.

Recommended Operating Conditions (T_A= -40 to 85°C unless otherwise noted)

Characteristic	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply voltage	V_{DD}	-	3	-	5.5	V
Output voltage (error code neglected)	V_{OUT}	Output OFF	-	-	7	V
		Output ON	-	1[1]	4[2]	V
Output voltage (error code acquired)	$V_{OUT,ED}$	Output OFF	-	-	V_{DD}-1.8	V
		Output ON	1.2	-	-	V
Output current	I_{OUT}	V_{DD}=3.3/5V	5	-	40/60	mA
Input voltage	V_{IH}	Input signals	0.7V_{DD}	-	V_{DD}	V
	V_{IL}	Input signals	0	-	0.3V_{DD}	V
OE/ pulse width	$t_{W(OE)}$	V_{DD}=3.3V/5V	120	-	-	ns
LA/ pulse width	$t_{W(L),ED}$	Error detection	200	-	-	ns

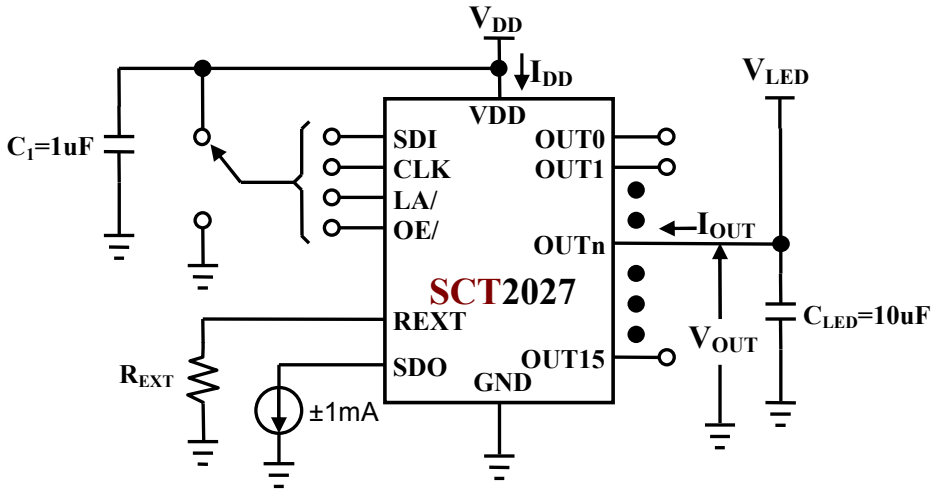
1. The output current keep constant in range of 5-60mA if V_{OUT}=1V.
   However, user can minimize V_{OUT} to reduce power dissipation according to used current, e.g., set V_{OUT} to 0.6V if I_{OUT}=20mA.
2. The maximum Vout is package thermal limited, user should keep Vout under maximum power dissipation.

Electrical Characteristics (V_{DD}=3.3/5V, T_A=25°C unless otherwise noted)

Characteristic		Symbol	Conditions	Min.	Typ.	Max.	Unit
Input voltage		V_{IH}	-	0.7V_{DD}	-	V_{DD}	V
		V_{IL}	-	0	-	0.3V_{DD}	V
SDO output voltage		V_{OH}	V_{DD}=3.3/5V, I_{OH}= -1mA	V_{DD}-0.4	-	-	V
		V_{OL}	V_{DD}=3.3/5V, I_{OL}=+1mA	-	-	0.4	V
Output leakage current		I_{OL}	V_{OUT}=7V	-	-	1	uA
Output current		I_{OUT}	V_{OUT}=1V, R_{EXT}=900Ω	-	21	-	mA
Current bit skew[1]		dI_{OUT1}	V_{OUT}=1V, R_{EXT}=900Ω	-	±1	±2	%
Chip skew[2]		dI_{OUT2}	V_{OUT}=1V, R_{EXT}=900Ω	-	±2	±4	%
Line regulation[3] I_{OUT} vs. V_{DD}		%/dV_{DD}	3V<V_{DD}<5.5V, V_{OUT}>1V, R_{EXT}=900Ω	-	±0.5	±1	%/V
Load regulation[4] I_{OUT} vs. V_{OUT}		%/dV_{OUT}	1V<V_{OUT}<4V, I_{OUT}=21mA, R_{EXT}=900Ω	-	±0.1	±0.5	%/V
Temp. regulation[5] I_{OUT} vs. T_A		%/dT_A	-20°C < T_A < 80°C, I_{OUT}=5mA~60mA, V_{DD}=5V	-	±0.005	-	%/°C
Open threshold voltage		V_{OD}	-	-	0.8	1.2	V
Short threshold voltage		V_{SD}	-	V_{DD}-1.8	V_{DD}-1.6	-	V
Pull-up resistor		R_{UP}	OE/	-	420	-	KΩ
Pull-down resistor		R_{DOWN}	LA/	-	400	-	KΩ
Supply current	OFF	$I_{DD(OFF)1}$	V_{DD}=3.3/5V, R_{EXT}=Open, OUT[0:15]=OFF	-	3	4	mA
		$I_{DD(OFF)2}$	V_{DD}=3.3/5V, R_{EXT}=900Ω, OUT[0:15]=OFF	-	6	8	
	ON	$I_{DD(ON)}$	V_{DD}=3.3/5V, R_{EXT}=900 Ω, OUT[0:15]=ON	-	8/9	11	

1. Bit skew=(I_{OUT}-I_{AVG}) / I_{AVG}, where I_{AVG}=($I_{OUT(max)}$+ $I_{OUT(min)}$)/2
2. Chip skew=(I_{AVG}-I_{CEN}) / I_{CEN}*100(%), where I_{CEN} is the statistics distribution center of output currents.
3. Line regulation=[I_{OUT}(V_{DD}=5.5V)-I_{OUT}(V_{DD}=3V)] / {[I_{OUT}(V_{DD}=5.5V)+I_{OUT}(V_{DD}=3V)]/2} / (5.5V-3V)*100(%/V)
4. Load regulation=[I_{OUT}(V_{OUT}=4V)-I_{OUT}(V_{OUT}=1V)] / {[I_{OUT}(V_{OUT}=4V)+I_{OUT}(V_{OUT}=1V)]/2} / (4V-1V)*100(%/V)
5. Temperature regulation=[I_{OUT}(T_A=80°C)-I_{OUT}(T_A=-20°C)] / {[I_{OUT}(T_A=80°C)+I_{OUT}(T_A=-20°C)]/2} / (80°C+20°C)*100(%/°C)

Test Circuit for Electrical Characteristics



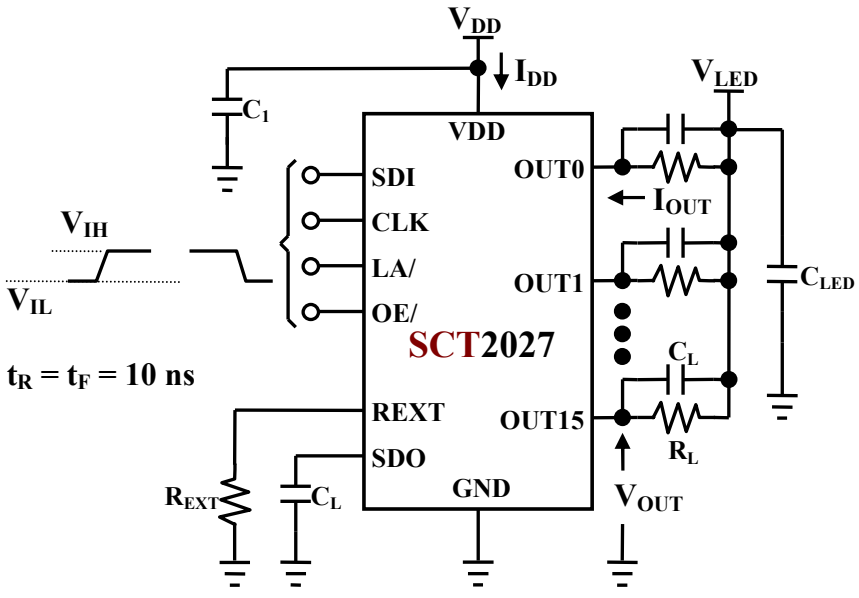
**Place C_1/C_{LED} as close to IC VDD/OUT pin(not supply source) as possible.*

Switching Characteristics (T_A=25°C unless otherwise noted)

Characteristic		Symbol	Conditions	Min.	Typ.	Max.	Unit
Propagation delay time (“L” to “H”)	CLK - OUTn	t_{PLH1}	V_{DD} = 3.3/5V V_{LED} = 5V V_{IH} = V_{DD} V_{IL}= GND R_{EXT} = 900Ω R_L = 180Ω C_L = 10pF C_1 = 1uF C_{LED} = 10uF	-	60/40	80	ns
	LA/ - OUTn	t_{PLH2}		-	60/40	80	ns
	OE/ - OUT0	t_{PLH3}		-	60/40	60	ns
	CLK - SDO	t_{PLH}		-	30/25	-	ns
Propagation delay time (“H” to “L”)	CLK - OUTn	t_{PHL1}		-	60/40	80	ns
	LA/ - OUTn	t_{PHL2}		-	60/40	80	ns
	OE/ - OUT0	t_{PHL3}		-	60/40	80	ns
	CLK - SDO	t_{PHL}		-	30/25	-	ns
Pulse width	CLK	$t_{W(CLK)}$		20/15	-	-	ns
	LA/	$t_{W(L)}$		20	-	-	ns
		$t_{W(L),ED}$		200	-	-	ns
	OE/	$t_{W(OE)}$		120	-	-	ns
Setup time for SDI		$t_{S(D)}$		5	-	-	ns
Hold time for SDI		$t_{HD)}$		15			ns
Setup time for LA/		$t_{S(L)}$		5	-	-	ns
Hold time for LA/		$t_{H(L)}$		5	-	-	ns
SDO rise time		t_{SDOR}		-	10	-	ns
SDO fall time		t_{SDOF}		-	10	-	ns
Output rise time of I_{OUT}		t_{OR}		-	35	50	ns
Output fall time of I_{OUT}		t_{OF}		-	35	50	ns
Delayed output		t_{DR}	OUTn to OUTn+1	-	1.2	-	ns
		t_{DF}		-	1.2	-	ns
Slow CLK rise time[1]		t_R	Cascade	-	-	500	ns
Slow CLK fall time		t_F		-	-	500	ns

1. It may not be possible to achieve the timing requirment for data transfer if t_R and t_F is too large during cascaded operation.

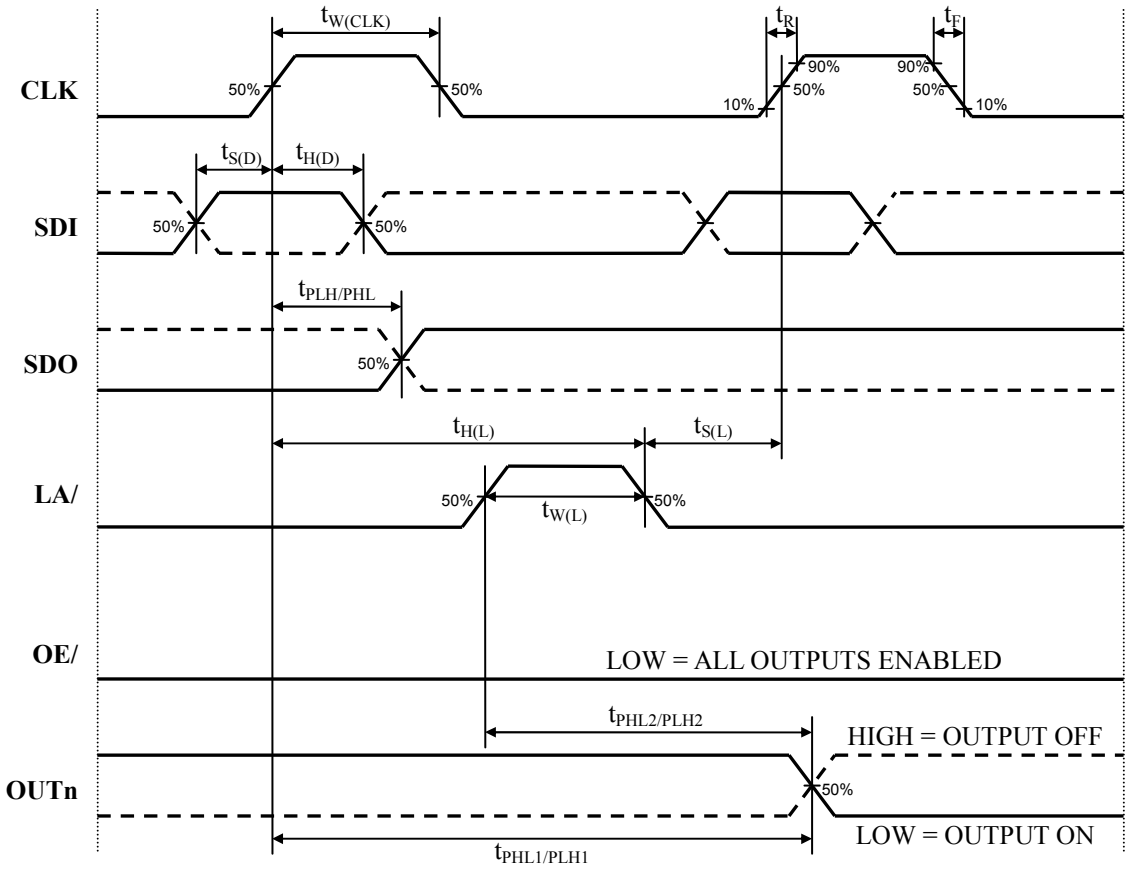
Test Circuit for Switching Characteristics



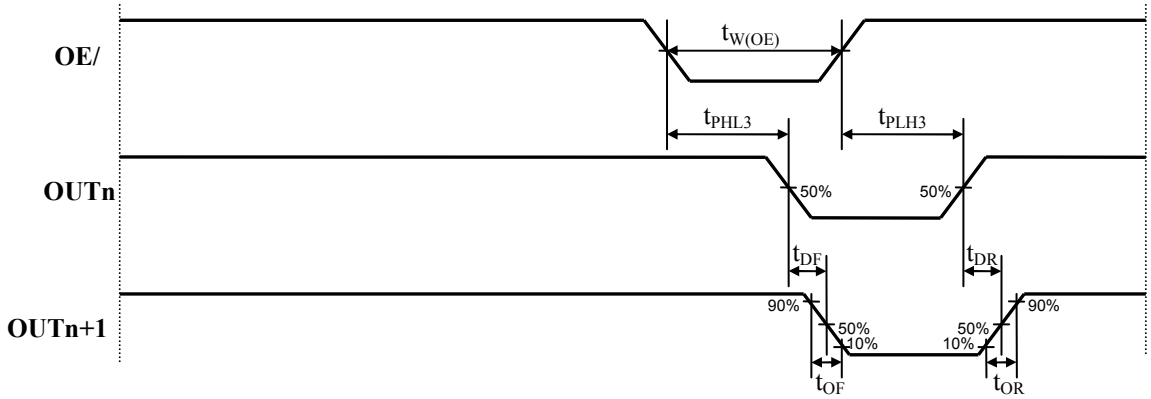
Place C_1/C_{LED} as close to IC VDD/OUT pin(not supply source) as possible.

Timing Waveform

LA/ Control Output

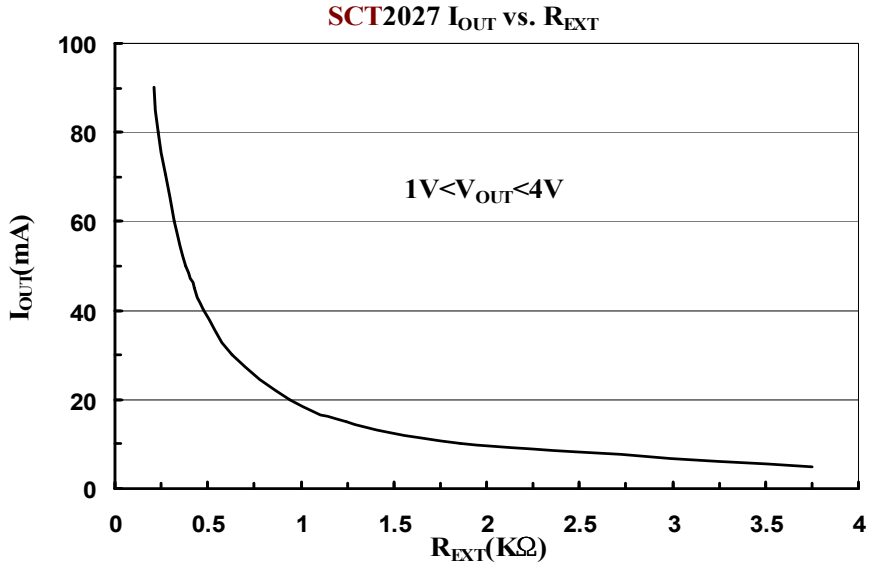


OE/ Control Output



Adjusting Output Current

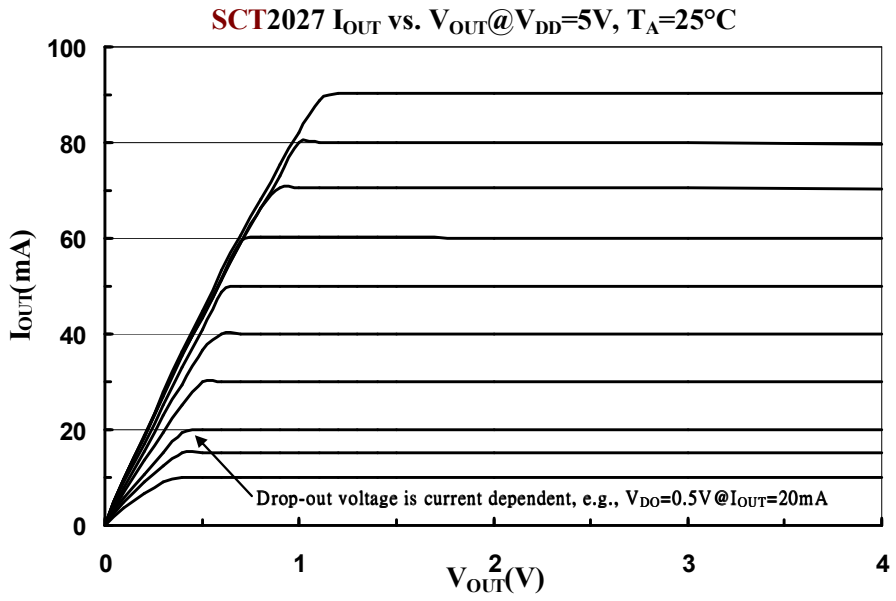
The SCT2027's output current (I_{OUT}) are set by one external resistor at pin REXT. The output current I_{OUT} versus resistance of R_{EXT} is shown as the following figure.



According to SCT20277' I-V curve, the output voltage should be larger than 1V to get 60 mA constant current. By applying proper output voltage, the SCT2027' output current set by an external resistor is approximate to: I_{OUT} = 30(630 / REXT) (mA) (chip skew < ±4%). Thus the output current is set to be about 21mA at REXT = 900Ω.

Output Characteristics

The current characteristic of output curve is flat. The output current can be kept constant regardless of the variations of LED forward voltage when $V_{OUT} > V_{DO}$(Drop-Out voltage). The relationship between I_{OUT} and V_{OUT} is shown below. The output voltage should be kept as low as possible to prevent the SCT2027 from being overheated.



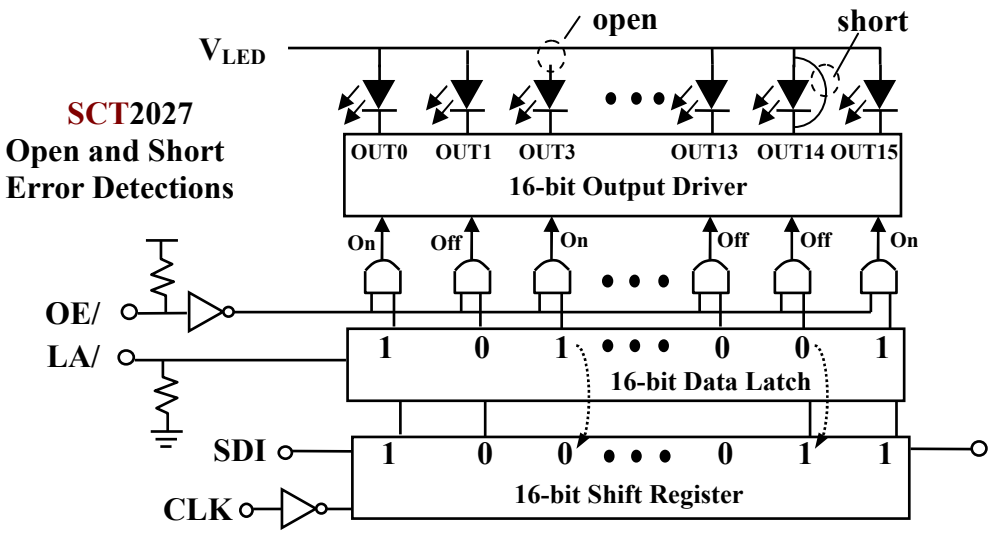
Error Detection

The SCT2027 acts fully the same as the SCT2024/6, simply latching data and driving the outputs. Also, the SCT2027 performs the Modeless™ error-detection function while driving the outputs. When display data are written into the SCT2027, the SCT2027 uses them to drives the outputs and checks each output status. If the output status is good, the bit '1' turns on the output and the bit '0' turns off the output. The SCT2027 detects the open error for bit '1' and the short error for bit '0'. The SCT2027 reports an open error by changing bit '1' into bit '0' and it reports a short error by overwriting bit '0' into bit '1'. When new display data continue to be written into the SCT2027, the error messages can be read from pins of SDO without changing any display data and operating mode.

Once the error-detection function is active, functions of open and short circuit detection are executed accompanying with LEDs' lights up or not. When data bits of latch are '1' and the OE/ pulse width is large than 120ns, the SCT2027 lights up LEDs and checks their open status. The SCT2027 updates bits of '1' of shift register with '0' at the moment when open-load errors are found. On the other hand, when data bits of latch are '0', the SCT2027 turns off LEDs, checks the 'short' status. Contents of the shift register will be changed from '0' to '1' if short-load errors are detected. Execution of error-detection does not affect any data or message of the LED display.

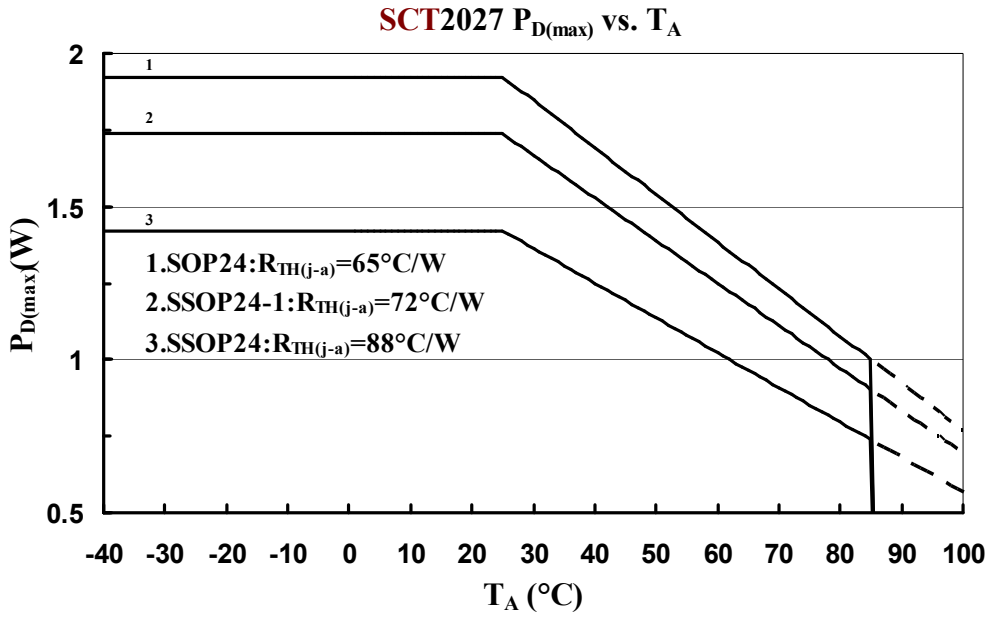
Since the error status is determined by comparing the output voltage value with the short and open threshold voltages, the operating output voltage should be set to be larger than 1.2V and less than V_{DD}-1.8V for accurate results of error checking.

Also, the OE/ signal should be active before error checking and the LA/ pulse width must be larger than 200ns, which is considered to be adequate to get a settled output voltage when checked by the internal circuits.



Power Dissipation

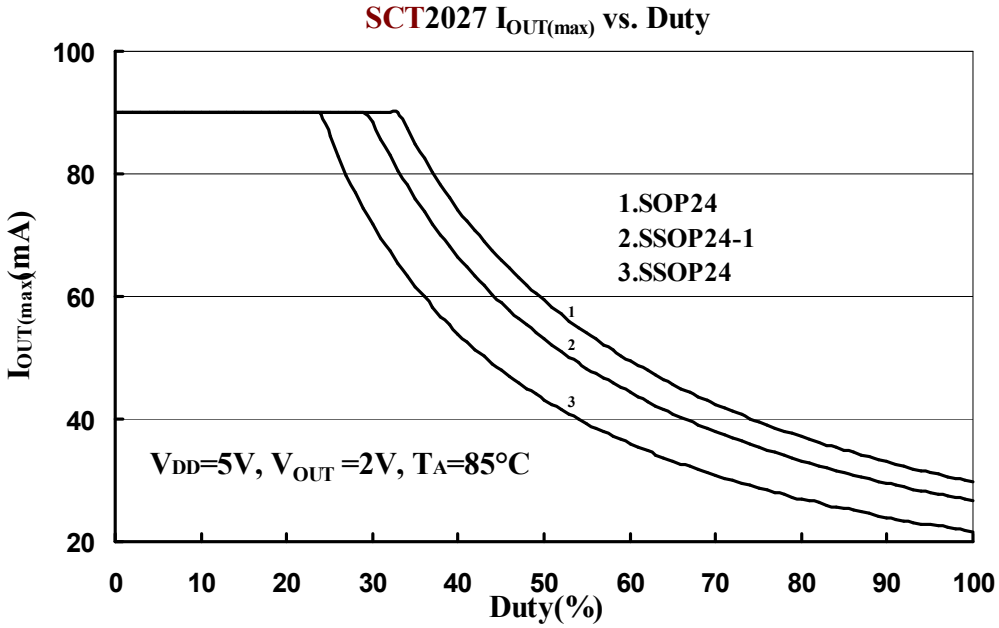
The maximum power dissipation ($P_{D(max)}$) of a semiconductor chip varies with different packages and ambient temperature. It's determined as $P_{D(max)}=(T_{J(max)} - T_A)/R_{TH(j-a)}$ where $T_{J(max)}$: maximum chip junction temperature is usually considered as 150°C, T_A: ambient temperature, $R_{TH(j-a)}$: thermal resistance. Since P=IV, for sinking larger I_{OUT}, users had better add proper voltage reducers on outputs to reduce the heat generated from the SCT2027.



Limitation on Maximum Output Current

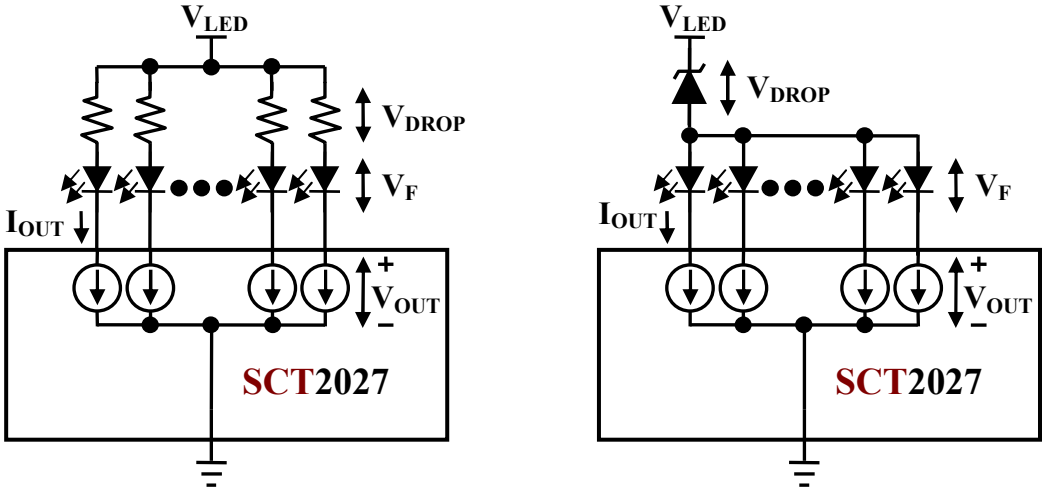
The maximum output current vs. duty cycle is estimated by:

$I_{OUT(max)}=(((T_{J(max)}-T_A)/R_{TH(j-a)})-(V_{DD}*I_{DD}))/V_{OUT}/Duty/N$ where $T_{J(max)}$=150°C, N=16(all ON)

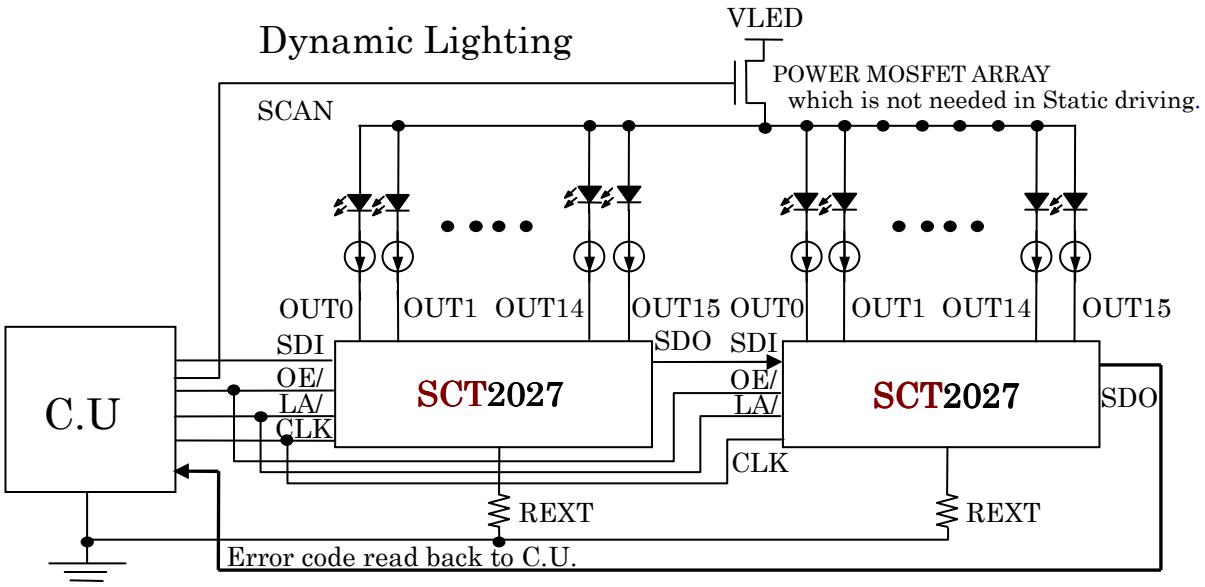


Load Supply Voltage (VLED)

The SCT2027 can be operated very well when V_{OUT} ranges from 1V to 4V. However, it is recommended to use the lowest possible supply voltage or set a voltage reducer to reduce the V_{OUT} voltage, at the same time reduce the power dissipation of the SCT2027. Suggested V_{OUT} is to be set greater than V_{DO} and less than 1V. The V_{DO} is dependent on the I_{OUT} current as indicated in section "Output Characteristics". Follow the diagram instructions shown below to lower down the output voltage. This can be done by adding additional resistor or zener diode, thus $V_{OUT}=V_{LED}-V_{DROP}-V_F$.



Typical Application Circuits

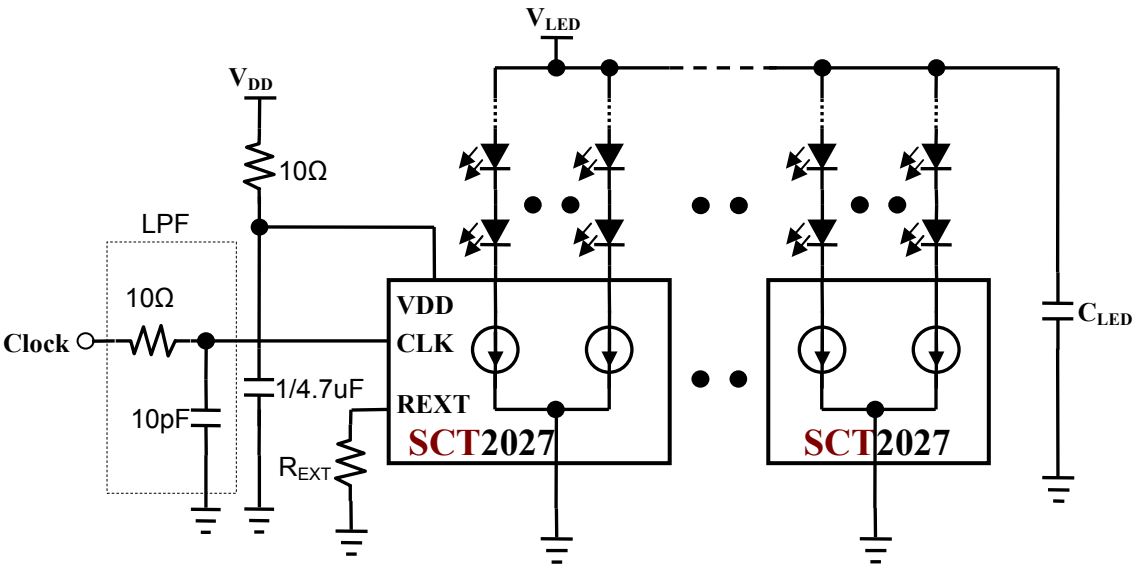


PCB Design Considerations

Use the following general guide-line when designing printed circuit boards (PCB):

Decoupling Capacitor

Place a decoupling capacitor e.g. 1uF between VDD and GND pins of SCT2027. Locate the capacitor as close to the SCT2027 as possible. This is normally adequate for static LED driving. For dynamic scan or PWM applications, it is suggested to add an additional capacitor of 4.7uF or more to each supply for every SCT2027. The necessary capacitance depends on the LED load current, PWM switching frequency, and serial-in data speed. Inadequate VDD decoupling can cause timing problems, and very noisy LED supplies can affect LED current regulation.



External Resistor (R_{EXT})

Locate the external resistor as close to the REXT pin as possible to avoid the noise influence.

Power and Ground

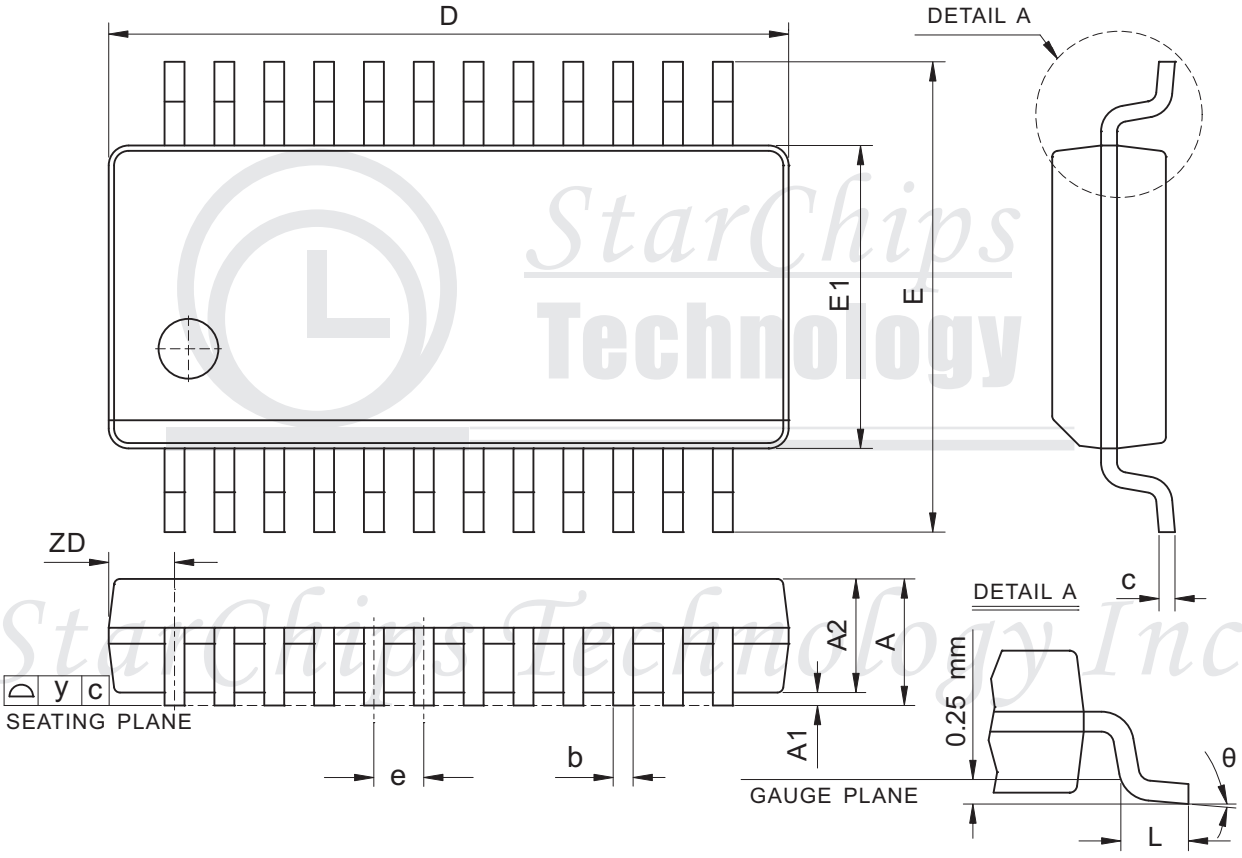
Maximizing the width and minimizing the length of VDD and GND trace improves efficiency and ground bouncing by effect of reducing both power and ground parasitic resistance and inductance. A small value of resistor, e.g., 10Ω (higher if I_{OUT} is larger) series in power input of the SCT2027 in conjunction with decoupling capacitor shunting the IC is recommended. Separating and feeding the LED power from another stable supply terminal V_{LED}, furthermore adding a capacitor C_{LED} greater than 10uF beside the LED are recommended. Please adapt C_{LED} according to total system current consumption.

EMI Reduction

To reduce the EMI radiation from system, an economical solution of RC low pass filter (LPF) is suggested to be used to lower the transient edge of clock input signal, as shown in the figure above. Using at least four layers PCB board with two interior power and ground planes is a good scheme to decrease the signal current path which is the source of radiation emission. As a result, EMI radiation can be decreased.

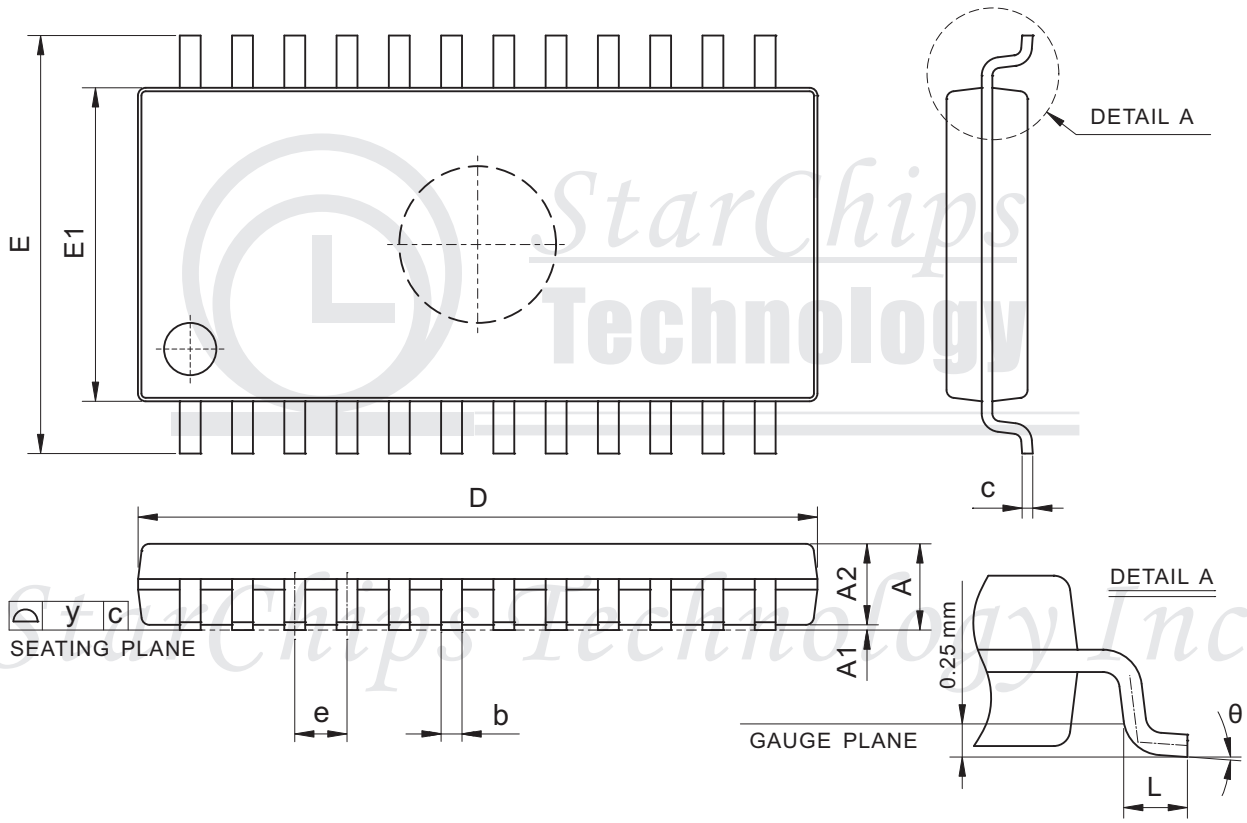
Package Dimension

SSOP24(check up-to-date version)



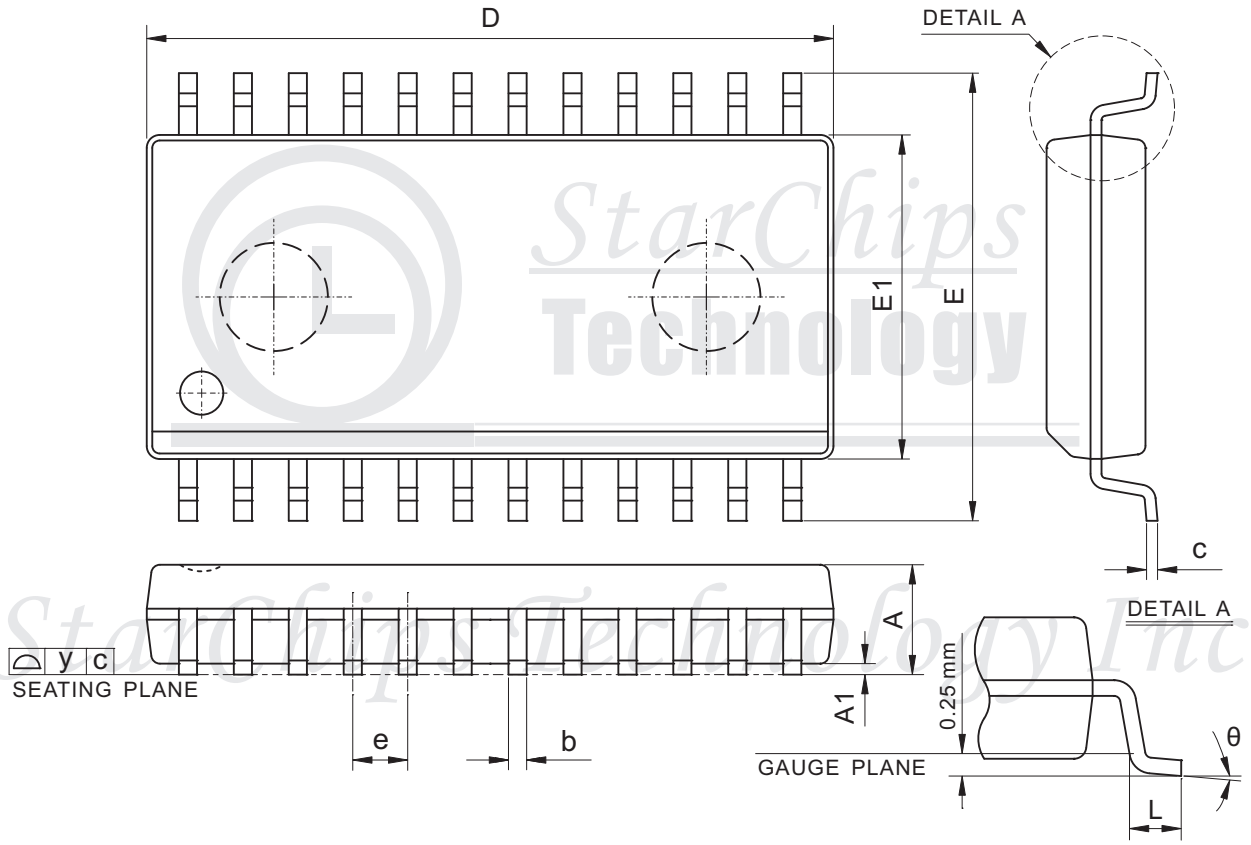
Symbol	Dimension (mm)			Dimension (mil)		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	1.35	1.63	1.75	53.1	64.2	68.9
A1	0.10	0.15	0.25	3.9	5.9	9.8
A2	-	-	1.50	-	-	59.1
b	0.20	-	0.30	7.9	-	11.8
c	0.18	-	0.25	7.1	-	9.8
D	8.56	8.66	8.74	337.0	340.9	344.1
E	5.79	5.99	6.20	228.0	235.8	244.1
E1	3.81	3.91	3.99	150.0	153.9	157.1
e	0.64 BSC			25.0 BSC		
L	0.41	0.64	1.27	16.1	25.0	50.0
y	-	-	0.10	-	-	3.9
ZD	0.84 REF			33.0 REF		
θ	0°	-	8°	0°	-	8°

SSOP24-1 (check up-to-date version)



Symbol	Dimension (mm)			Dimension (mil)		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	-	-	1.90	-	-	74.8
A1	0.05	0.10	0.15	2.0	3.9	5.9
A2	1.30	1.50	1.70	51.2	59.1	66.9
b	0.30	0.40	0.52	11.8	15.7	20.5
c	0.10	0.15	0.27	3.9	5.9	10.6
D	12.80	13.00	13.20	503.9	511.8	519.7
E	7.70	8.00	8.30	303.1	315.0	326.8
E1	5.80	6.00	6.20	228.3	236.2	244.1
e		1.00 BSC			39.4 BSC	
L	0.25	0.45	0.65	9.8	17.7	25.6
y	-	-	0.10	-	-	3.9
θ	0°	-	10°	0°	-	10°

SOP24(check up-to-date version)



Symbol	Dimension (mm)			Dimension (mil)		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	2.35	-	2.65	92.5	-	104.3
A1	0.10	-	0.30	3.9	-	11.8
b	0.33	-	0.51	13.0	-	20.1
c	0.23	-	0.32	9.1	-	12.6
D	15.20	-	15.60	598.4	-	614.2
E	10.00	-	10.65	393.7	-	419.3
E1	7.40	-	7.60	291.3	-	299.2
e	1.27 BSC			50.0 BSC		
L	0.40	-	1.27	15.7	-	50.0
θ	0°	-	8°	0°	-	8°
y	-	-	0.10	-	-	3.9

Revision History(check up-to-date version)

Data Sheet Version	Remark
V01_03	Disable thermal shutdown; remove QFN/DIP package

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