

# TPIC6C596 Power+ Logic™ Shift Register Application

Thomas E. Cosby

MSDS Power Control Products

## ABSTRACT

The TPIC6C596 is a serial-in parallel-out, Power+Logic™ 8-bit shift register with low-side switch DMOS outputs rating of 100 mA per channel. The device is designed to drive resistive and inductive loads and is particularly well suited as an interface between a microcontroller and LEDs or lamps. The TPIC6C596 is an enhancement of the TPIC6C595, where the shift register serial output (SER OUT) is clocked on the falling edge of the serial clock to provide additional hold time in applications where several devices are cascaded. This report focuses on three of the many possible applications for the TPIC6C596.

## Contents

<b>LED Sign</b> .....	<b>2</b>
<b>Graphic Status Panel</b> .....	<b>3</b>
<b>Fault Status Indicator</b> .....	<b>4</b>
Timing Considerations With the TPIC6C596 .....	5
Incandescent Lamps .....	5
Power and Thermal Considerations .....	5
<b>Conclusion</b> .....	<b>6</b>

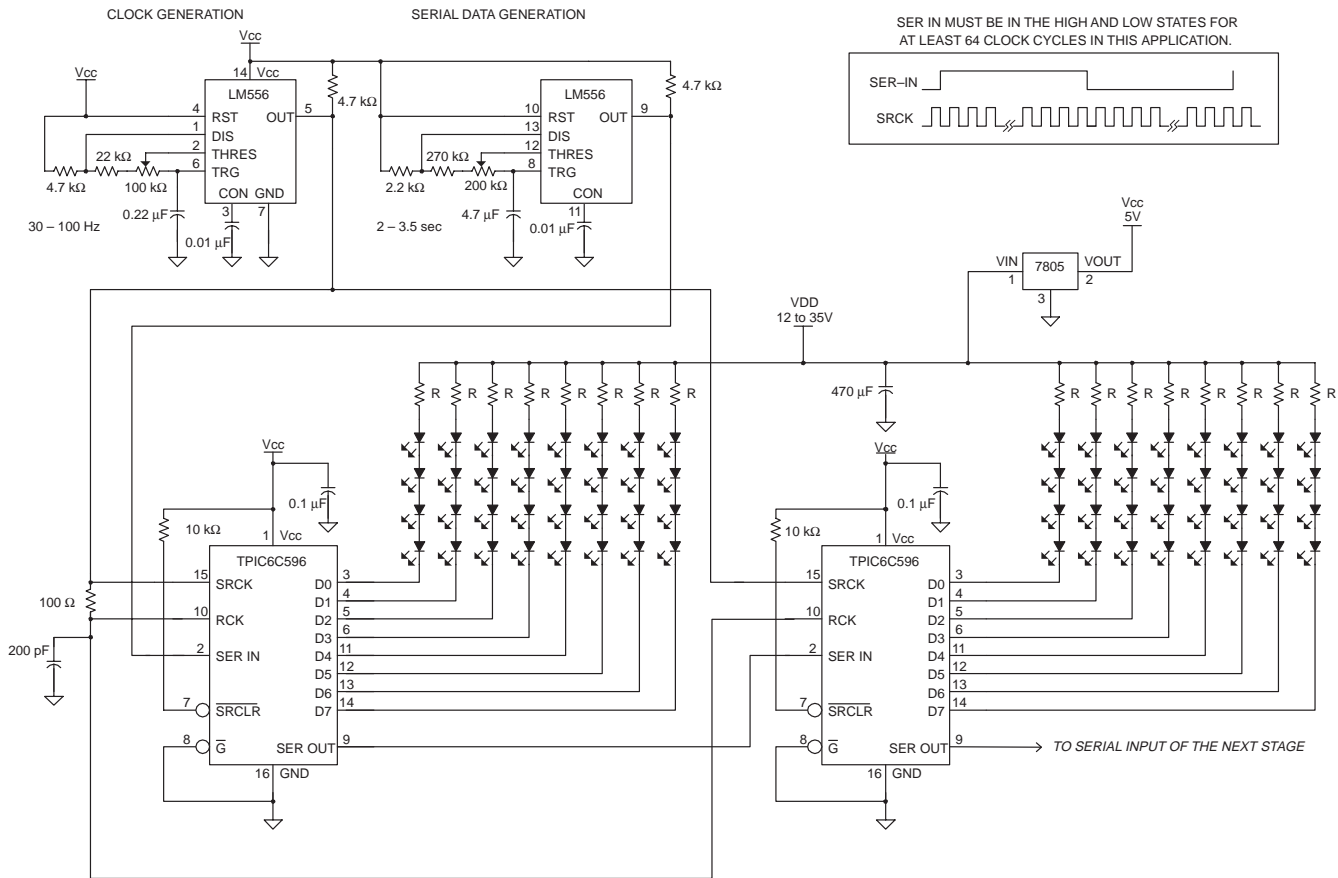
## List of Figures

1 The Self-Writing LED Display Sign .....	2
2 Graphic Status Panel for Industrial Machines .....	3
3 Real-Time Fault Status Indicator .....	4
4 Timing Minimums, Setup, and Hold .....	5
5 Lamp Inrush Current at Turn-On .....	5

## LED Sign

In the first example, eight power shift registers are cascaded and used to turn on a string of 64 LEDs or lamps sequentially. In this application, register clock (RCK) is clocked, with only slight delay, each time the shift register clock (SRCK) is clocked; hence, the display is updated after each bit of data is shifted in. The serial input data (SER IN) is held alternately high and low for any period greater than 64 clocks causing the

LEDs to strobe on from left to right and remain on until they strobe off in the same manner. With the LEDs arranged sequentially as in a written message, the design gives the appearance of writing, resulting in an attractive and dynamic display sign. The output enable ( $\overline{G}$ ) can be used for blinking or blanking the LEDs, if desired. Only one IC is required in addition to the shift registers, an LM556 timer to generate the clocks. An example of the circuit is illustrated in Figure 1.



**Figure 1. The Self-Writing LED Display Sign**

## Graphic Status Panel

In the second example, two TPIC6C596 power shift registers are cascaded and used to turn on LEDs or lamps in a graphic panel representing status, action, and faults of an industrial machine. In this case, the lamps must be updated after all 16 bits of the machine status word have been loaded into the serial shift registers. The machine controller outputs the status word to the serial input (SER IN) while clocking the shift register clock (SRCK). After the 16th clock, a pulse to the register clock (RCK) transfers the data to the storage registers. After the 16th clock, a pulse to the register clock (RCK) transfers the data to the storage registers. If

output enable ( $\overline{G}$ ) is low, then the lamps are turned on corresponding to the status word with ones being on and zeros off. With this simple scheme, three outputs from the system controller can turn on 16 lamps using only two ICs as illustrated in Figure 2. A graphic panel, with embedded LEDs representing machine operation, communicates machine status to the operator faster than other types of indicators and is more economical than computer graphic displays. When more lamps are required, it is only necessary to cascade additional shift registers while maintaining the same three input control signals.

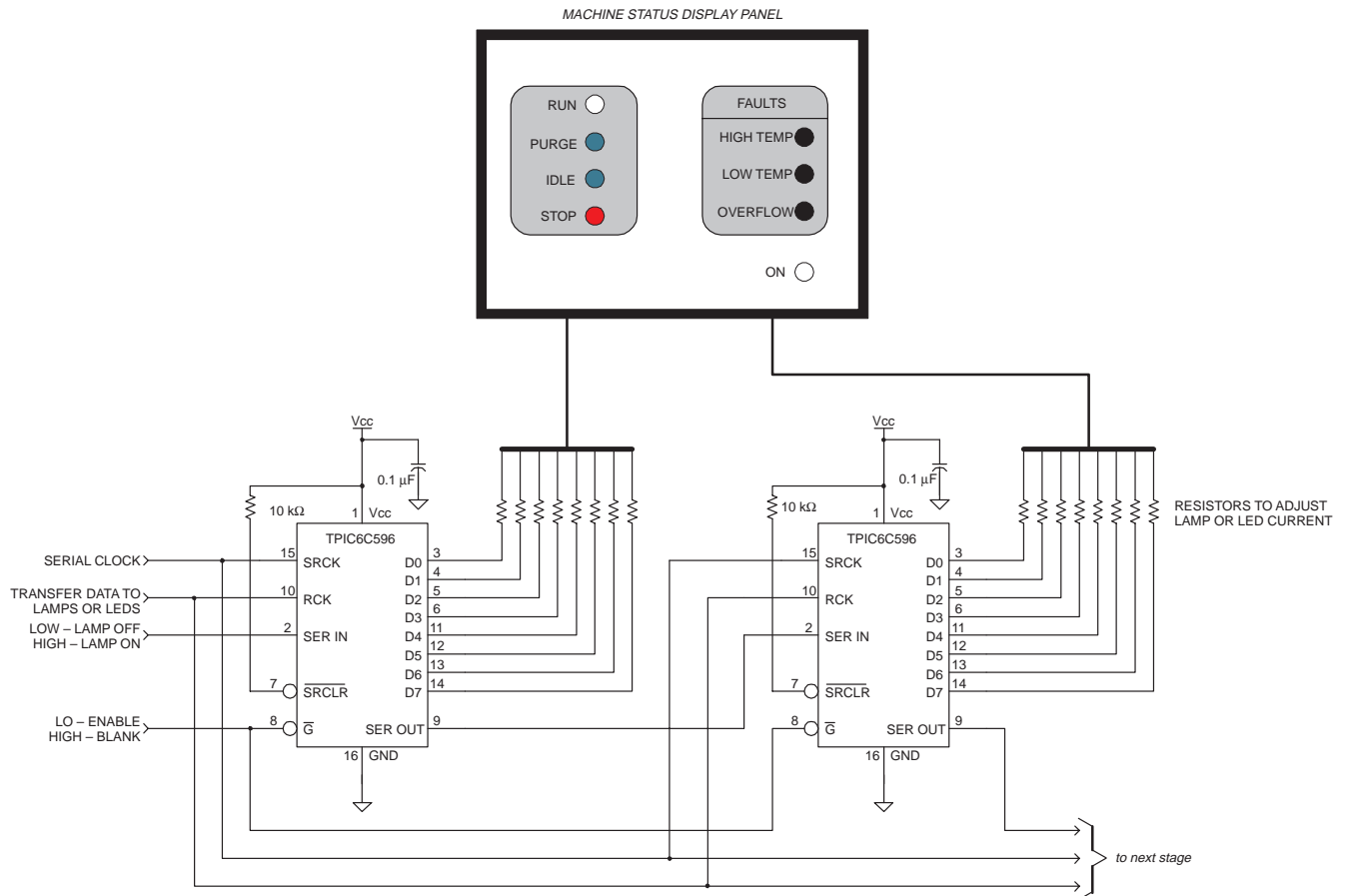


Figure 2. Graphic Status Panel for Industrial Machines

## Fault Status Indicator

In the third example, a single TPIC6C596 power shift register receives the serial fault diagnostic byte directly from a FET predriver with diagnostic capability. In this application, a microcontroller is sending parallel data to a 6-channel FET predriver, the TPIC46L01, which is driving a power FET array that switches the loads (see Figure 3). When a load becomes open, shorted, or when the battery voltage is out of range, the fault terminal ( $\overline{\text{FLT}}$ ) transitions low. The fault is monitored by the microcontroller and, in response to the falling edge of the fault terminal, sends 8 serial clocks (SCLK) to the FET predriver to transfer the fault diagnostic data. The serial data output (SDO) and the serial clock

(SCLK) of the predriver are connected directly to the serial input (SER IN) and the shift register clock (SRCK) of the TPIC6C596 power shift register, respectively; therefore, direct transfer of the fault diagnostic information to the serial-in parallel-out shift register is achieved. After the 8th clock, the microcontroller sends a register clock (RCK) to the TPIC6C596 to transfer the fault data to the storage register and to the LEDs providing visual indication of the fault condition. The fault data is also captured by the microcontroller where additional diagnostic analysis can be performed by the software. The TPIC6C596 and the LEDs provide the user a very quick and easy medium to see which load has a problem without the need for additional diagnostic equipment.

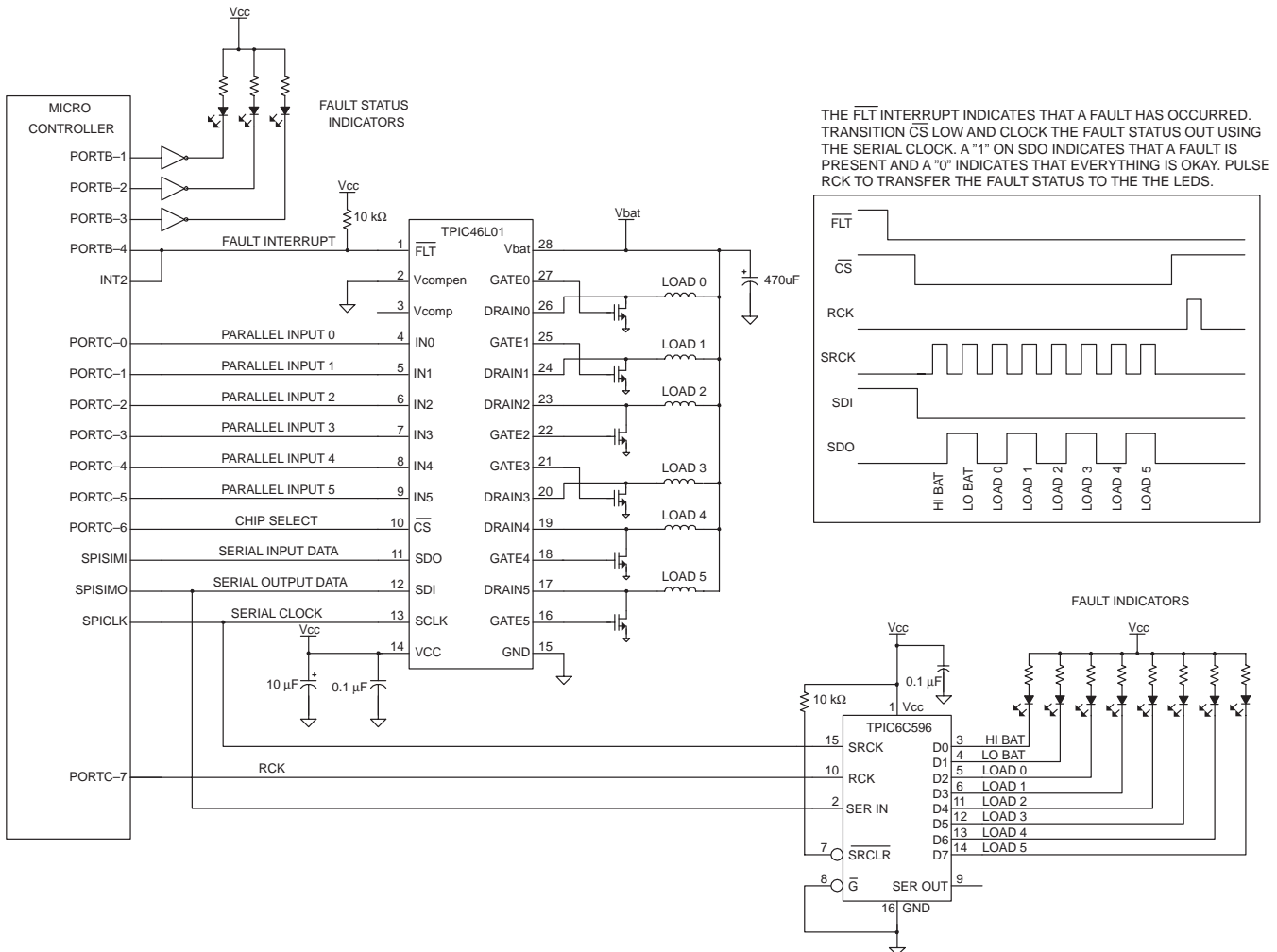


Figure 3. Real-Time Fault Status Indicator

## Timing Considerations With the TPIC6C596

In the example in Figure 1, data is clocked into the serial data register and transferred to the storage register bit-by-bit. The data must be stable on SER IN at least 20 ns before SRCK. Data must be stable at the input of the internal storage register, prior to RCK, as shown in Figure 4. While the data transfer propagation delay is internal to the IC and cannot be measured by the user, it can be determined by comparison of the input to the output data while varying the SRCK to RCK delay time. The resistor and capacitor in Figure 1, at the RCK terminal (#10), causes the necessary delay of approximately 20 ns. If SRCK and RCK are tied together, hence no delay, the data in the storage register and on the outputs of the device will be one clock behind the data in the serial register. In this display sign application, there is no apparent difference if the data was one clock late. In an application where the output is required to be an exact image of the input data, this would be more significant.

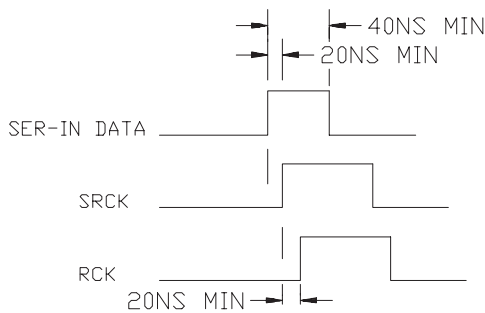


Figure 4. Timing Minimums, Setup, and Hold

In the example in Figure 2, the data update reflects the current status of the machine and any flickering of the lamps is considered undesirable. The data is clocked into the serial data registers in even increments, 16, 24, 32, etc., 8 bits for each IC. After the last rising edge of SRCK plus a delay, RCK can be pulsed.

In the example in Figure 3, RCK is pulsed after the falling edge of the eighth SRCK while SRCK is low. There are no timing concerns with this method.

## Incandescent Lamps

Figure 5 shows the inrush current of an incandescent lamp. Trace 2 is the drain current and trace 4 is the drain voltage. Note that at the high peak current portion of the waveform, the drain voltage indicates that the transistor is not saturated at currents above 250 mA, which is the specified peak pulse current limit for this transistor. Lamps should be chosen with inrush currents less than 250 mA. A suitable running current range would be 40 to 60 mA maximum. The lamp shown has a running current of 80 mA. The output transistors of the TPIC6C596 have a continuous current rating of 100 mA.

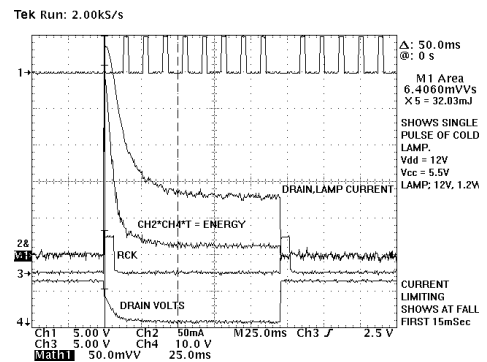


Figure 5. Lamp Inrush Current at Turn-On

## Power and Thermal Considerations

The voltages required to drive the loads in the above three examples could vary widely; however, the power dissipation of the TPIC6C596 remains a function of the number of outputs on, the load current, and the  $r_{DS(on)}$ . It is only necessary to know the load current to figure the power dissipation. Some assumptions made are: the loads shown are not inductive, the update rates are slow as compared to transistor switching times, and all outputs are on 100% of the time (worst case).

Given:

$r_{DS(on)} = 12 \Omega$  for TPIC6C596 at maximum temperature

$N = 8$ , number of outputs on

$I_D$  = drain current for each transistor

$P_T$  = total power dissipation capability for the package

$R_{\theta JA} = 115^\circ\text{C/W}$ , thermal resistance junction-to-ambient temperature of D package

$T_A$  = ambient temperature

$T_R$  = temperature rise over ambient

$T_J = 150^\circ\text{C}$ , junction temperature maximum

$I_{LED} = 20 \text{ mA}$ , typical

$I_{LAMP} = \text{lamp rated at } 40 \text{ mA at } 28 \text{ V}$

Power dissipation for TPIC6C596 package.

$$P_T = I_D^2 \times r_{DS(on)} \times N \quad (1)$$

Power dissipation for the LEDs, the LED current limit resistor was chosen for a 20 mA current.

$$P_T = (20 \text{ mA})^2 \times 12 \Omega \times 8 = 38.4 \text{ mW}$$

Power dissipation for the lamps, for  $V_{DD} = 28 \text{ V}$ ,

$$P_T = (40 \text{ mA})^2 \times 12 \Omega \times 8 = 153.6 \text{ mW}$$

The temperature rise over ambient for the type N package can be calculated as follows,

$$P_T = \frac{T_R}{R_{\theta JA}} \text{ or } T_R = R_{\theta JA}, ^\circ\text{C/W} \times P_T \quad (2)$$

For a TPIC6C596 type D package driving the lamp,

$$T_R = 115^\circ\text{C/W} \times 153.6 \text{ mW} \approx 17.7^\circ\text{C}$$

Where:  $T_A = T_J - T_R$

Therefore,  $T_A = 150^\circ\text{C} - 17.7^\circ\text{C} = 132.3^\circ\text{C}$

The absolute maximum case temperature rating for the TPIC6C596 is  $125^\circ\text{C}$ ; therefore, the device has a junction temperature margin when switching these loads.

A more practical approach may be to find the maximum drain current for each output at a given ambient temperature. Assume that all eight outputs are being used and the maximum ambient temperature is to be  $70^\circ\text{C}$ .

From equation 1,

$$P_T = I_D^2 \times r_{DS(on)} \times N \text{ or}$$

$$I_D = \sqrt{\frac{P_T}{r_{DS(on)} \times N}}$$

From equation 2,

$$P_T = \frac{T_R}{R_{\theta JA}}$$

Where  $T_R = T_J - T_A$  or

$$P_T = \frac{T_J - T_A}{R_{\theta JA}}$$

Substituting equation 2 into equation 1,

$$I_D = \sqrt{\frac{T_J - T_A}{R_{\theta JA} \times r_{DS(on)} \times N}} \text{ or}$$

$$I_D = \sqrt{\frac{150 - 70}{115 \times 12 \times 8}} = 0.085 \text{ Amps}$$

## Conclusion

The TPIC6C596 power shift register integrates a 74HC595-type shift register and an eight-channel low-side configured FET output stage to provide a very economical solution for switching LEDs. The serial output is designed to increase the hold time margin for cascaded applications, allowing maximum flexibility in device placement and signal waveshaping.

## **IMPORTANT NOTICE**

Texas Instruments and its subsidiaries (TI) reserve the right to make changes to their products or to discontinue any product or service without notice, and advise customers to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgment, including those pertaining to warranty, patent infringement, and limitation of liability.

TI warrants performance of its semiconductor products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are utilized to the extent TI deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

Customers are responsible for their applications using TI components.

In order to minimize risks associated with the customer's applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance or customer product design. TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of TI covering or relating to any combination, machine, or process in which such semiconductor products or services might be or are used. TI's publication of information regarding any third party's products or services does not constitute TI's approval, warranty or endorsement thereof.