TLC6C598-Q1 and TLC6C5912-Q1 Shift Register LED Driver Application

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ABSTRACT

The TLC6C598-Q1 and TLC6C5912-Q1 are serial-in parallel-out, 8-bit and 12-bit shift register with low-side switch DMOS outputs rating of 50 mA per channel. These devices are designed mainly for automotive to drive resistive loads and are particularly well-suited as an interface between a microcontroller and LEDs. This report clarifies the difference against TPIC6C596 and focuses on four of the many possible industrial applications.

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1 Devices Guide and Comparison

Comparing to TPIC6C596, TLC6C598-Q1 and TLC6C5912-Q1, implement several enhancements for LED driver applications. The TLC6C598-Q1 is pin-to-pin compatible with the TPIC6C596. Table 1 shows a comparison list among 3 devices.

Table 1. Comparison List for 3 Devices

	TPIC6C596	TLC6C598-Q1	TLC6C5912-Q1
AECQ-100	Yes	Yes	Yes
Max output continuous current per channel	100 mA	50 mA	50 mA
Number of Channels	8	8	12
Output Inductive clamp voltage	33 V	No	No
Max break down drain voltage	33 V	40 V	40 V
ESD rating	2500 V	2000 V	2000 V
V_{CC} range	4.5 V to 5.5 V	3 V to 5.5 V	3 V to 5.5 V
I_{CC} (Logic supply current), All outputs off	20 µA	0.1 µA ($\overline{G}$ = high[(1)]) 16 µA ($\overline{G}$ = low[(1)])	0.1 µA ($\overline{G}$ = high[(1)]) 16 µA ($\overline{G}$ = low[(1)])
I_{CC} (Logic supply current), All outputs on	150 µA	88 µA	130 µA
I_{CC} (Logic supply current), f_{SRCK} = 5 MHz, C_L = 30 pF	1200 µA	200 µA	300 µA
Output slew rate	(C_L = 30 pF, I_D = 75 mA) t_r is 100 ns t_f is 80 ns	(C_L = 30 pF, I_D = 48 mA) t_r is 210 ns t_f is 128 ns	(C_L = 30 pF, I_D = 48 mA) t_r is 250 ns t_f is 200 ns
Thermal shut down	No	Yes	Yes

(1) $\overline{G}$ = low enables thermal shutdown circuit and consumes more quiescent current.

TLC6C598/12-Q1 bring the following benefits from the improvements:

1. Max break down drain voltage of TLC6C598/12-Q1 is 40 V. The load supply can be connected to a 12-V car battery directly, as the device is capable to survive load dump up to 40 V.
2. Wider V_{CC} operating range from 3 V to 5.5 V supports both 3.3-V and 5-V power supply rails.
3. Optimized slew rate improves EMI performance.
4. Thermal shutdown function enhances system reliability.
5. Dedicated to drive LED and resistive loads by removing the output inductive clamp. Note that the TLC6C598/12-Q1 could not be used to drive inductive loads without external clamping circuits.

2 LED Sign

In the first example, 2 pcs eight power shift registers TLC6C598-Q1 are cascaded and used to turn on a string of 64 LEDs, 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, two TLC555-Q1 timers to generate the clocks

An example of the circuit is illustrated in Figure 1.

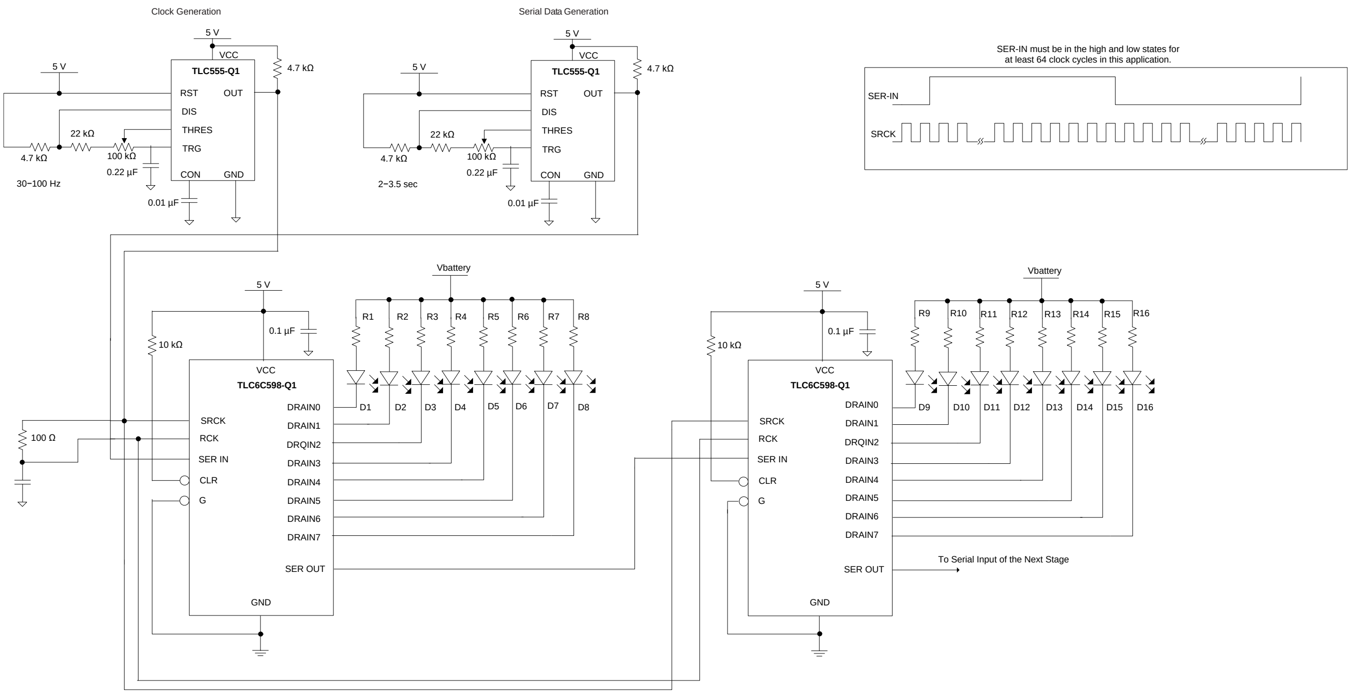

Figure 1. Self-Writing LED Display Sign

3 Graphic Status Panel

In the second example, one TLC6C598-Q1 and one TLC6C5912 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 20 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 20th 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 20 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.

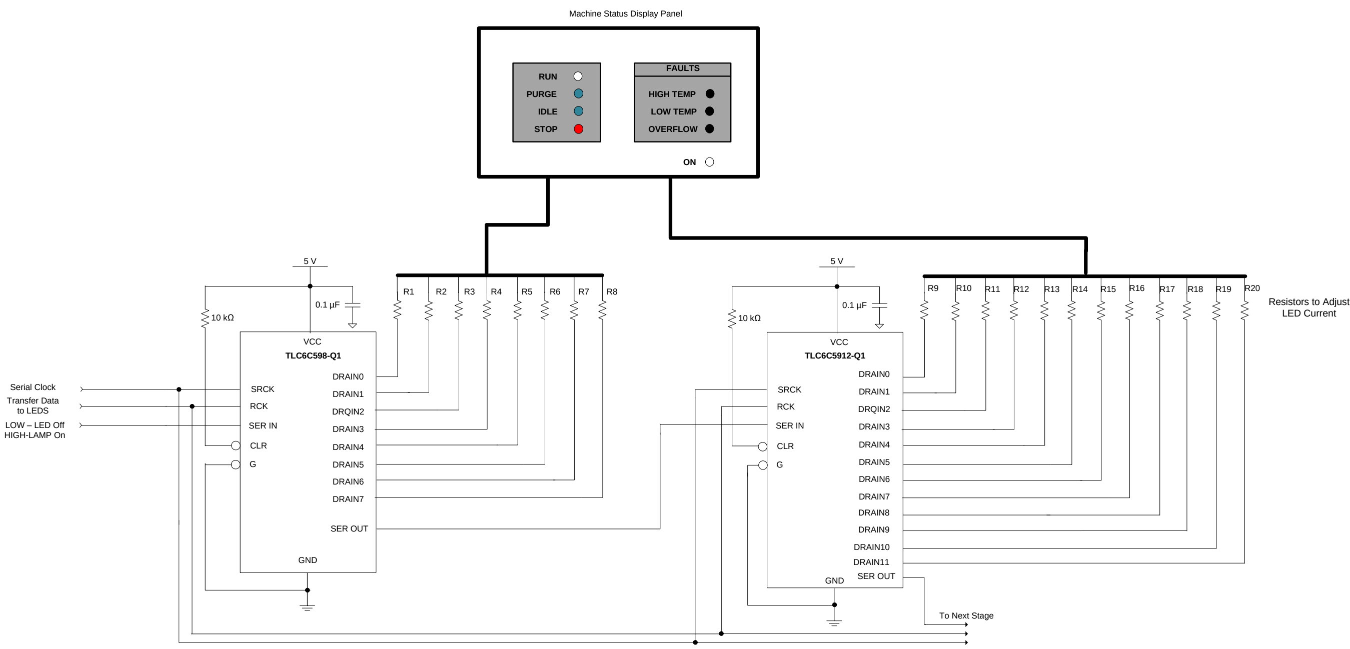

Figure 2. Graphic Status Panel for Industrial Machines

4 Fault Status Indicator

In the third example, a single TLC6C598-Q1 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 (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 TLC6C598-Q1, respectively; therefore, direct transfer of the fault diagnostic information to the serial-in parallel-out shift register is achieved. After the eighth clock, the microcontroller sends a register clock (RCK) to the TLC6C598-Q1 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 TLC6C598-Q1 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.

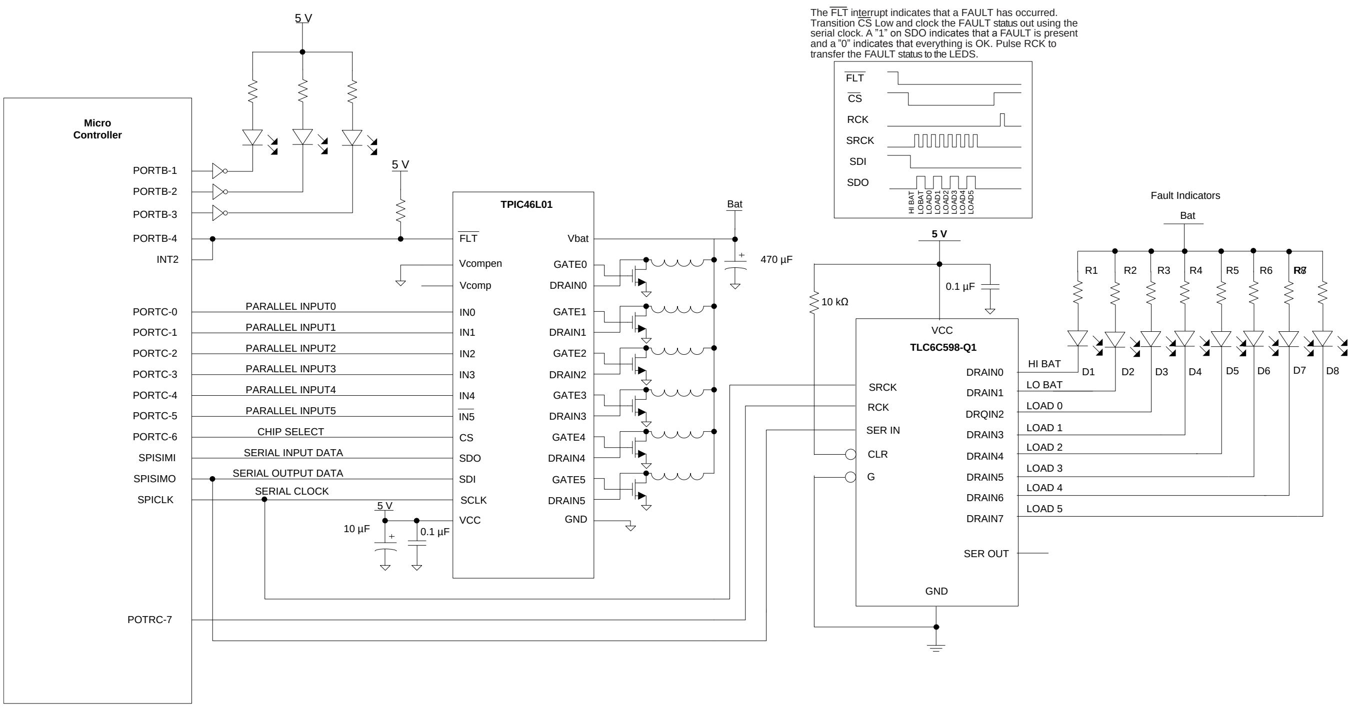

Figure 3. Real-Time Fault Status Indicator

5 LED Dot Matrix

As a 12-channel shift register, one single TLC6C5912-Q1 can drive maximum of 36 LEDs when scanning columns and rows. Table 2 shows the max LED number based on row (A) and column (B) structure.

Table 2. Maximum LED Number Based on Structure

Row Number (A)	Column Number (B)	Total LED Number
11	1	11
10	2	20
9	3	27
8	4	32
7	5	35
6	6	36
5	7	35
4	8	32
3	9	27
2	10	20
1	11	11

Figure 4 is the schematic of 35 LEDs (7 × 5) dot matrix driver solution, controlled by 4 GPIOs of MCU. It is a simple implementation with minimum MCU GPIO resource. Vsupply can be connected to up to 40 V directly.

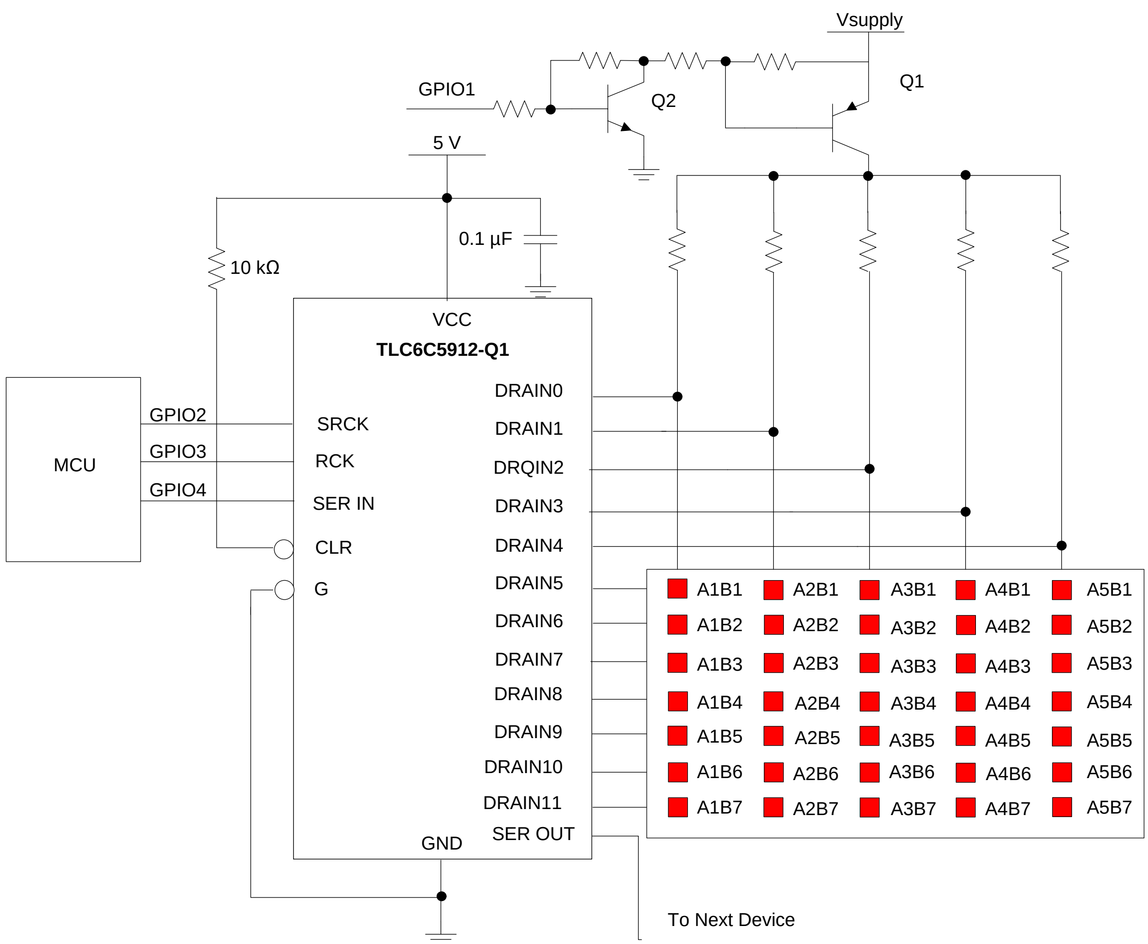

Figure 4. LED DOT Matrix

Here is the process to turn on A1B1, A2B2, A3B4, A4B5, and A5B6 in the dot matrix.

1. Turn on Q1
2. Turn on Drain1, Drain2, Drain3, Drain4, Drain5 and turn off the others.
3. Turn on Drain0, Drain2, Drain3, Drain4, Drain6 and turn off the others.
4. Turn on Drain0, Drain1, Drain3, Drain4, Drain8 and turn off the others.
5. Turn on Drain0, Drain1, Drain2, Drain4, Drain9 and turn off the others.
6. Turn on Drain0, Drain1, Drain2, Drain3, Drain11 and turn off the others.

Normally 200 Hz above scanning frequency is needed to avoid flickering.

6 Timing Considerations With the TLC6C598-Q1 and TLC6C5912-Q1

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.

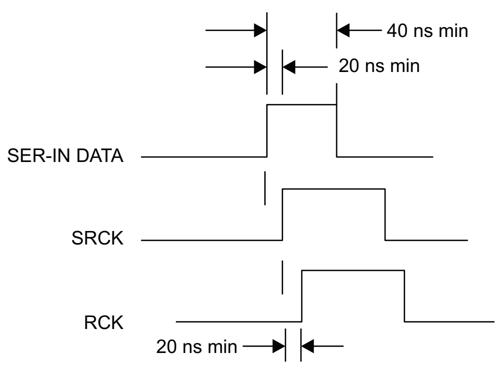

Figure 5. Timing Minimums, Setup, and Hold

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, and so forth, 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.

7 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 TLC6C598-Q1 or TLC6C5912-Q1 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:

$r_{DS(on)}$ = 18.2 Ω for TLC6C598-Q1 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
$R_{\theta JA}$ = 129.4°C/W, thermal resistance junction-to-ambient temperature of PW package
T_A = ambient temperature
T_R = temperature rise over ambient
T_J = 150°C, junction temperature maximum
I_{LED} = 20 mA, typical
I_{LAMP} = lamp rated at 28 mA at 16V

Power dissipation for TLC6C598-Q1 package.

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

Power dissipation for the LEDs, the LED current limit resistor was chosen for a 20 mA current when supply voltage is 12V.

$$P_T = (20\text{ mA})^2 \times 18.2\ \Omega \times 8 = 58.2\text{ mW} \tag{2}$$

When supply is 16V,

$$P_T = (28\text{ mA})^2 \times 18.2\ \Omega \times 8 = 114.2\text{ mW} \tag{3}$$

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

$$P_T = \frac{T_R}{R_{\theta JA}} \quad \text{or} \quad T_R = R_{\theta JA}, {}^\circ\text{C / W} \times P_T \tag{4}$$

For a TLC6C598-Q1 PW package driving the lamp.

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 85°C for the automotive application.

From Equation 1:

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

or

$$I_D = \sqrt{\frac{P_T}{r_{DS(on)} \times N}} \tag{5}$$

T_R = 129.4°C/W × 114.2 mW ≈ 14.8°C

Where: $T_A = T_J – T_R$

Therefore, T_A = 150°C – 14.8°C = 135.2°C

The absolute maximum case temperature rating for the TLC6C598-Q1 is 125°C; therefore, the device has a junction temperature margin when switching these loads.

$$P_T = \frac{T_R}{R_{\theta JA}} \tag{6}$$

From Equation 4

Where:

$$T_R = T_J - T_A$$

or

$$P_T = \frac{T_J - T_A}{R_{\theta JA}} \tag{7}$$

Substituting Equation 4 into Equation 1,

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

Or

$$I_D = \sqrt{\frac{150 - 85}{129.4 \times 18.2 \times 8}} = 0.063 \text{ Amps} \tag{8}$$

The max current per channel for TLC6C598-Q1 is 50 mA, so the max current is 50 mA.

8 Conclusion

The TLC6C598/12-Q1 is compatible with the TPIC6C596 with enhancements for LED applications. The serial output is designed to increase the hold time margin for cascaded applications, allowing maximum flexibility in device placement and signal waveshaping. The devices can be used in various automotive and industrial applications.

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