Application Report

SGLA003–December 2019

TLC3702 TLC3704 Family Application Note

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ABSTRACT

TI has confirmed improper operation of the TLC370x family when any channel transitions less than 50us of any other channel. During this time, the trailing channel will experience an extended propagation delay. This Application Note describes the issue and what type of applications to avoid.

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Trademarks

1 Devices Covered By This Application Note

All TLC3702 and TLC3704 family devices, including "Q1" and "EP" devices. Herein referred to as the TLC370x.

2 Summary

When any channel of a TLC307x micropower comparator family transitions within 50us of any other channel, the trailing channel will experience a delay of up to 10 times the normal propagation delay. Also during this time, the output waveform is distorted and the supply current increases during the output transition time. All channels are equally affected and it does not matter which channel transitions first. Transitions can be positive or negative on any channel, however the low to high output transition is the worst case.

3 Cross-Channel Influenced Delay

When one channel transitions within 50µs of the other channel, this can cause the lagging channels propagation delay to extend. The output also becomes distorted during this time.

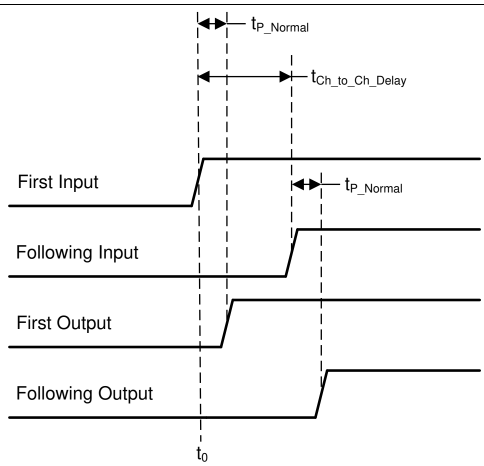

Figure 1. Expected Comparator Behavior

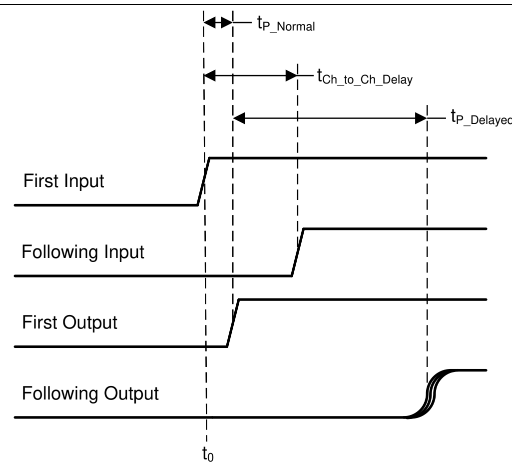

Figure 2. Actual TLC370x Behavior

Figure 1 shows expected comparator behavior when one channel transitions slightly before another channel. Both outputs should be delayed only by the normal, specified propagation delay period (t_p) without any influence from the other channel.

Figure 2 shows the actual TLC370x behavior when one channel transitions before another channel. The first channel propagation delay is normal (t_{p_Normal}), but the second channel suffers a prolonged delay ($t_{p\_Delayed}$) of up to 10 times the normal propagation delay (t_{p_Normal}) when the channel to channel delay ($t_{Ch\_to\_Ch\_Delay}$) is less than 50µs.

Figure 3 shows the actual behavior when one both channels are transitioned simultaneously (inputs tied together). The two channels compete with each other, resulting in the random jittering of both channel outputs.

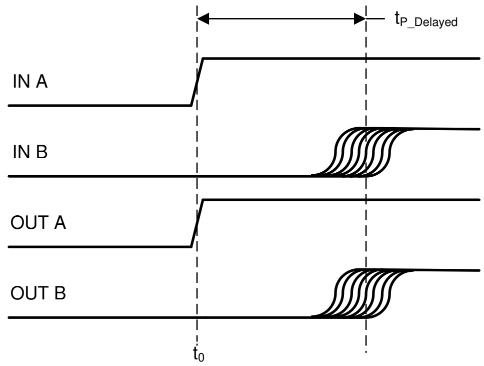

Figure 3. Actual Simultaneous Transition Behavior

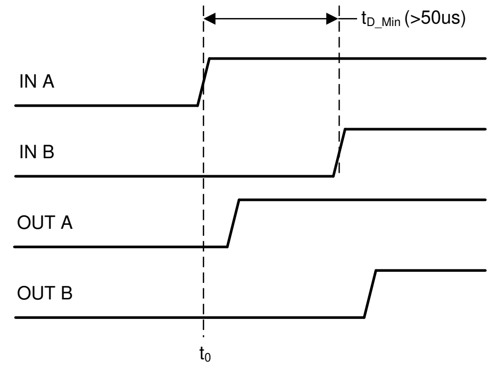

Figure 4. Behavior When Greater Than Minimum Channel to Channel Delay

Actual delays depend on supply voltage and the channel to channel delay time, with 16V supply voltage being the worst. At the minimum supply voltage (3V or 4V), the delay may not even be noticeable for all except the most time-critical or jitter sensitive applications.

Figure 5 to Figure 8 show the measured propagation delay time between channels for various supply voltages. It is recommended to base designs on values 30-50% larger than the actual measured delays to account for temperature, device and lot-to-lot variations.

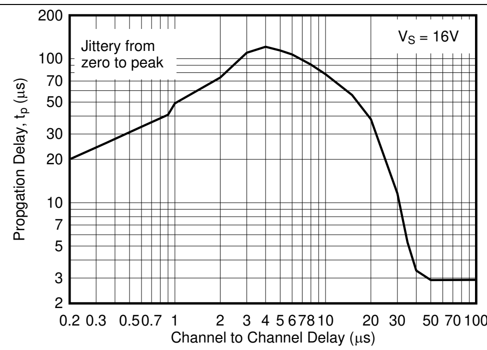

Figure 5. Propagation Delay vs. Channel to Channel Delay for 16V

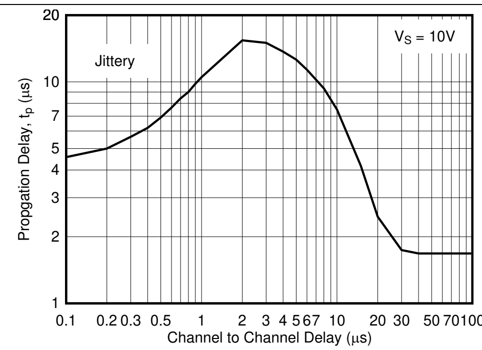

Figure 6. Propagation Delay vs. Channel to Channel Delay for 10V

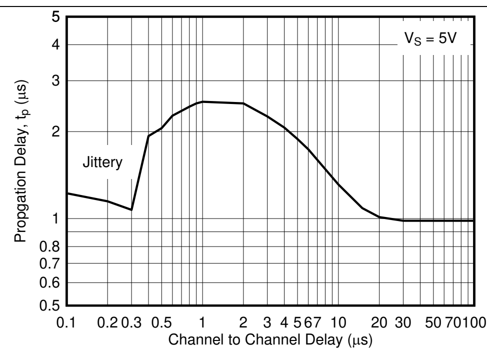

Figure 7. Propagation Delay vs. Channel to Channel Delay for 5V

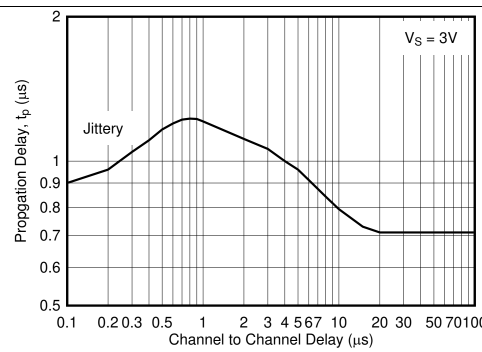

Figure 8. Propagation Delay vs. Channel to Channel Delay for 3V

In addition, a single channel can affect itself if the toggle rate is fast enough (time period is less than 50µs). This will be seen as an increase in propagation delay as the toggle frequency period approaches the minimum delay time. The result being a constant output delay period with a jittery trailing end.

4 High Supply Current During Delay Period

During the period where the output is delayed, the average supply current will increase due to higher "shoot-through" currents during the delay time. Note that during the delay time, the output edges are rounded, resulting in a "S" shaped output waveform. Due to the reduced internal biasing, both the sinking and sourcing output devices are partially on for a short period - resulting in large supply "shoot-through" currents during this period.

Figure 9 through Figure 16 below shows the worst-case 16V supply input and output waveforms, as well as the measured supply current (after supply bypass cap). The I/O and supply current waveforms are graphs are "stacked" in pairs to show the timing relationships. For the I/O scope photos, the right-top "CH1→CH2" measurement is the Ch A propagation delay measurement, the middle-right "CH3→CH4" measurement is the Ch B propagation delay, and the middle-bottom "CH1→CH4" measurement is the channel to channel delay. The top blue/red set is the comparator channel A and the bottom cyan/green set is the comparator channel B. Current waveforms is measured between the bypass capacitor and the supply pin.

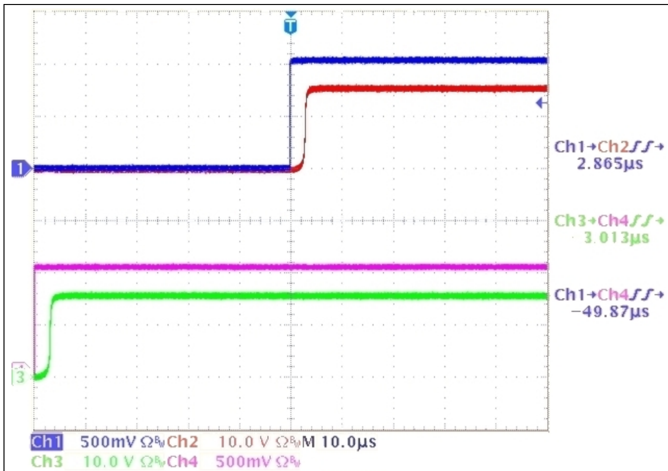

Figure 9. 16V I/O Waveforms at 50µs Channel Delay

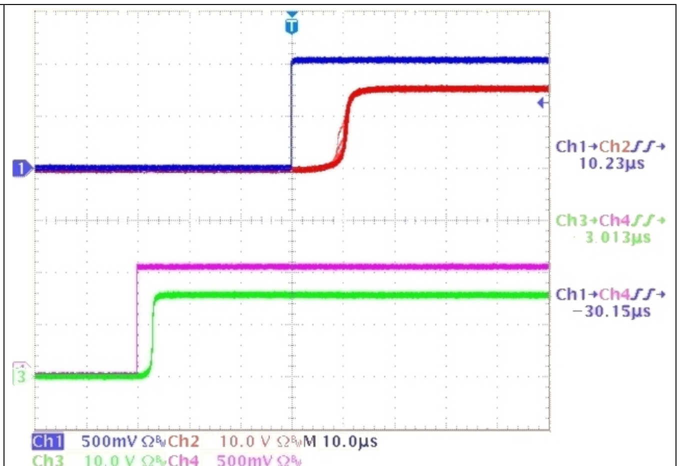

Figure 10. 16V I/O Waveforms at 30µs Channel Delay

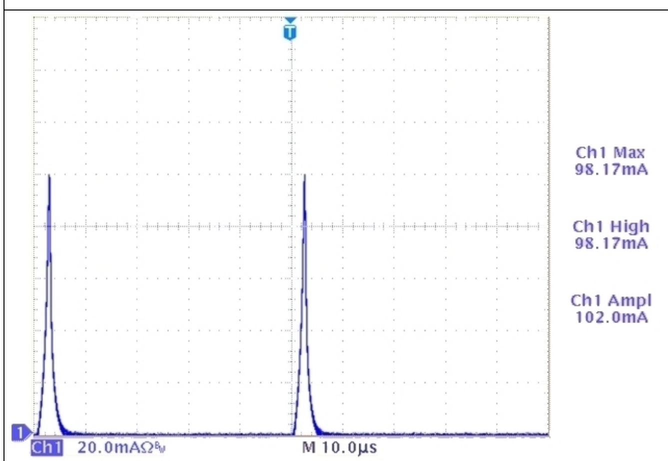

Figure 11. 16V Supply Current Waveforms at 50µs Channel Delay

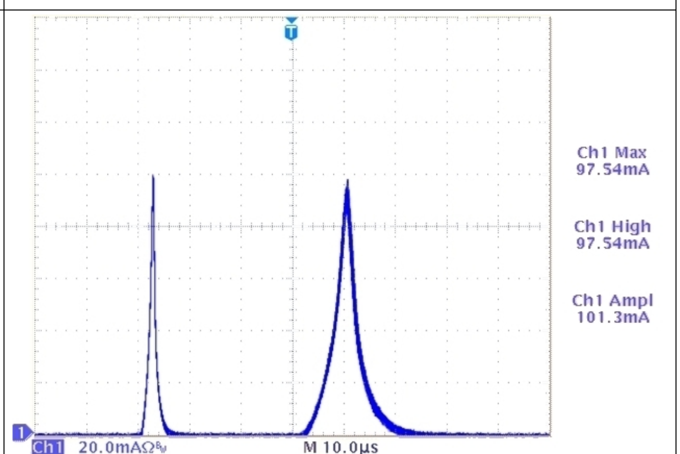

Figure 12. 16V Supply Current Waveforms at 30µs Channel Delay

Figure 9 and Figure 11 show the "Normal" output waveform and supply current spikes with a 50µs delay between channels. Each channel has a propagation delay of about 3µs, which is typical for a full 16V output swing.

Figure 10 and Figure 12 show the waveforms with a 30µs delay between channels. Because the channel to channel delay is less than 50µs, it is starting to see the delay effects. The "leading" channel B propagation delay is 3µs, but "trailing" channel A propagation delay has now extended out to 10.2µs. The Channel A output waveform is also starting to take on the tell-tale "S" shape with a resulting widening of the corresponding supply current spike.

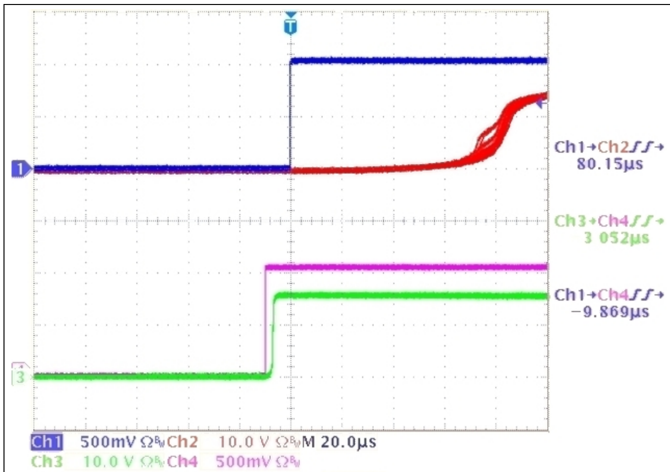

Figure 13. 16V I/O waveforms at 10µs Channel Delay

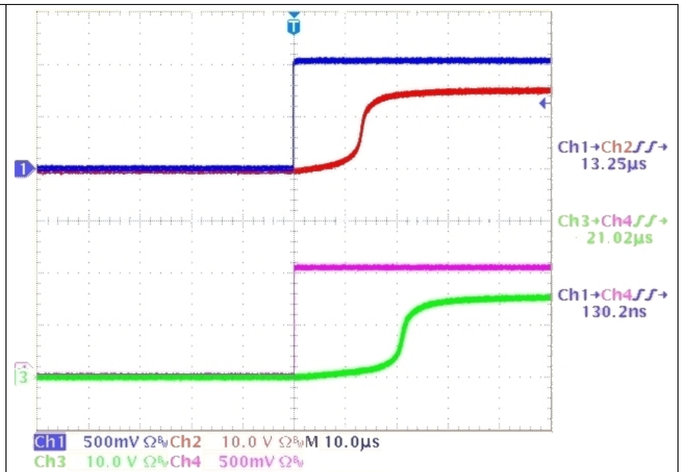

Figure 14. 16V I/O waveforms at "Zero" Channel Delay

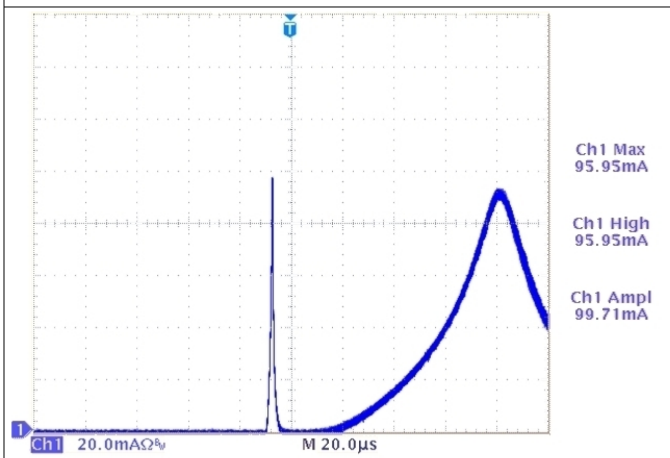

Figure 15. 16V Supply Current waveforms at 10µs Channel Delay

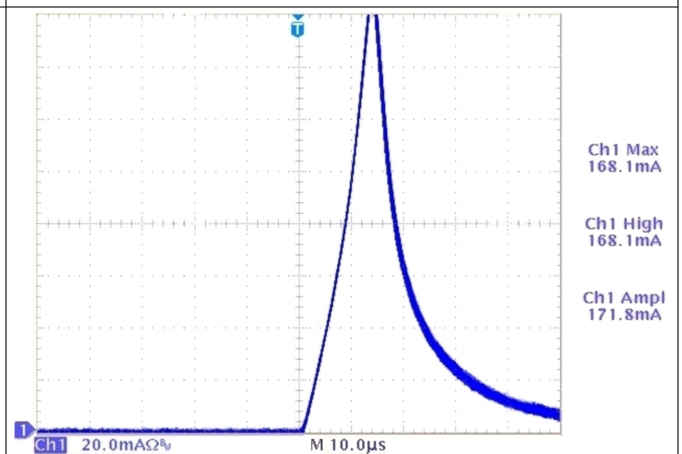

Figure 16. 16V Supply Current waveforms at "Zero" Channel Delay

Figure 13 and Figure 15 show a more pronounced effect at a channel-to-channel delay separation of 10µs. The "S" shaped output is more pronounced and the channel A propagation delay has extended out to 80µs. The "leading" channel B prop delay still remains at 3µs.

Figure 14 and Figure 16 show the effect when the channels are driven at nearly the same time (the timing has been adjusted for worst case in the photos). Both channels propagation delays have extended and varying. While not visible in the static scope photo, the two channel propagation delay times are randomly varying as the two channels compete for position. Both of the supply current spikes have widened and are now overlapping and have combined to form one large spike of almost double the supply current amplitude.

Table 1 below shows the measured supply current shoot-through spikes and average current with a 10 kHz square wave input. The 16V measurements are with a 1kHz input to allow time for the spikes to settle.

Table 1. Spike Amplitudes and Average Supply Current at 10 kHz (1)

Supply Voltage	"Normal" Spike Amplitude	"Normal" Spike Width	"Normal" average supply current	"Delayed" Spike Amplitude	"Delayed" Spike width	"Delayed" average supply current
3 V	3 mA	1 µs	28 µA	7 mA	1 µs	31 µA
5 V	13 mA	1 µs	70 µA	22 mA	2 µs	100 µA
10 V	47 mA	2 µs	511 µA	85 mA	8 µs	2.6 mA
16 V (2)	98 mA	6 µs	320 µA (2)	168 mA	50 µs	10 mA (2)

(1) Input signal is 10kHz Square Wave, 50pF//10MΩ load to GND. Highest peak current shown. 10uF bypass capacitance.
(2) Frequency changed to 1 KHz for 16V - this also decreases the average supply current.

Figure 17 shows the average supply current versus toggling frequency with one channel toggling and all other channels set output low. Outputs are loaded with 50pF.

Figure 18 shows the average supply current versus toggling frequency with both channels toggling simultaneously (Channel to Channel delay = 0s).

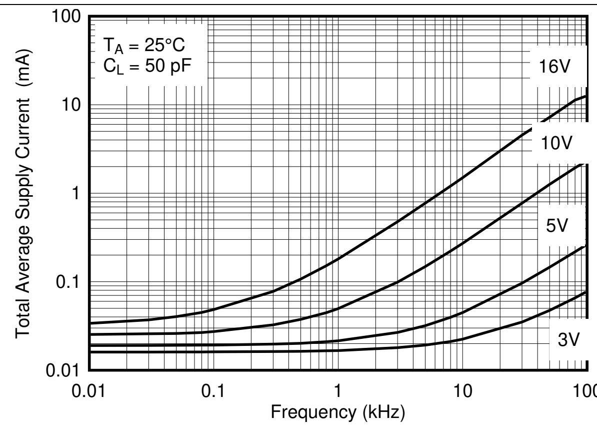

Figure 17. Supply Current vs. Toggle Frequency One Channel Toggling Only

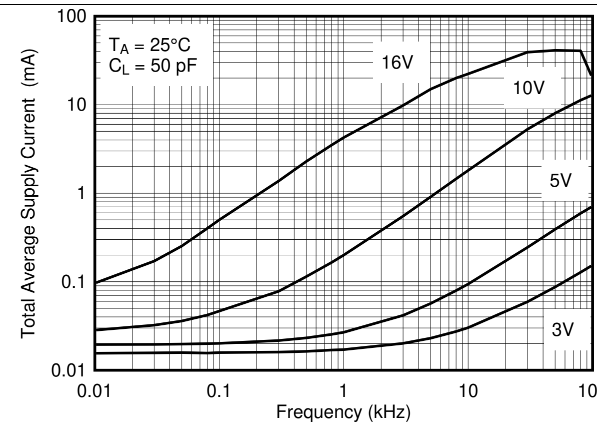

Figure 18. Supply Current vs. Toggle Frequency Both Channels Toggling Simultaneously

5 Applications That Will Be Negatively Impacted

Applications where the comparator outputs are expected to transition simultaneously or within 50µS of each other, or have toggle frequencies of >10kHz.

Applications where comparator power supply is derived from a high impedance or unregulated source that cannot handle the transitory high average currents. This is particularly true of supplies using a dropping resistance and a zener.

6 Recommendations for Existing Designs

Use larger than normal bypass capacitors that can supply the needed transient supply currents. We recommend 1uF or more total bulk bypassing using low impedance capacitors, such as ceramic, placed as close to the device as possible. This is particular critical for "soft", high impedance supplies like coin cells or similar micropower power supplies.

7 Recommended Replacement Devices

For applications with supply voltages between 5 and 15V, and can tolerate a slower (4µs) propagation delay, please see the LMC6762. We do not currently have an alternate quad device with push-pull output with similar propagation delay and pinout. For applications with supply voltages less than 6V, we recommend the TLV7012, or TLV7032.

The TLV1805 is a 40V push-pull output, but is currently only available as a single.

8 References

- TLC3702 Datasheet - SLCS013
- TLC3704 Datasheet - SLCS117
- TLC3702-EP Datasheet - SGLS127
- TLC3702-Q1 Datasheet - SGLS156
- TLC3704-Q1 Datasheet - SGLS191

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