

# Implementing LED Drivers in Altera MAX Series

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Altera® MAX® II, MAX V, MAX 10, MAX 3000A, MAX 7000A, MAX 7000B, and MAX 7000S devices can be used in this example application.

Discrete LED driver chips are common on many system boards. Supported Altera devices offer unique capabilities that allow you to integrate single or multiple LED driver chips into a single device.

## Related Information

- [Design Example for MAX II](#)  
Provides the MAX II design files for this application note (AN 286).
- [Design Example for MAX 10](#)  
Provides the MAX 10 design files for this application note (AN 286).

## Commercial LED Driver Chips

Many LEDs, such as the seven-segment display, are common-anode LEDs. The LEDs anode connects to  $V_{CC}$  and each cathode connects to an output pin of the current-sinking LED driver chip. The driver chip sinks the DC current required to drive the display, and the LED turns on when the driver chip's output pins drive low. Current-regulating circuits are implemented inside the LED driver chips.

Current-sinking LED drivers are more common than current-sourcing drivers.

**Table 1: Current-Sinking LED Driver Chips**

Lists some common LED driver chips manufactured by Texas Instruments, National Semiconductor, and Toshiba. The manufacturer datasheets provide additional information about LED driver chips.

LED Driver Chip	Description
<b>Texas Instruments</b>	
TLC5905	LED driver with shift registers, data latch, and constant current circuitry
TLC5910	LED driver with shift registers, data latch, on-chip phase-locked loop (PLL) for gray scale generation and constant current
TLC5911	LED driver with shift registers, data latch, on-chip PLL for gray scale generation and constant current
TLC5921	LED driver with shift register, data latch, and current-sink constant current circuitry
<b>National Semiconductor</b>	
DS8874	9-digit shift input LED driver

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ISO  
9001:2008  
Registered



LED Driver Chip	Description
DS8863	MOS-to-LED 8-digit driver
DS8963	MOS-to-LED 8-digit driver
<b>Toshiba</b>	
TB62701AN	16-bit constant current LED driver with shift register and latch functions
TB62705	8-bit constant current LED driver with shift register and latch functions
TB62706	16-bit constant current LED driver with shift register and latch functions
TB62707	8-bit constant current LED driver with latch functions

## Implementing LED Drivers in Supported Altera Devices

When using a supported Altera device as an LED driver chip, place a current-limiting resistor between the cathode side of the LEDs diode and the supported Altera device I/O. The LEDs anode is tied to  $V_{CC}$ , and is turned on when the device I/O drive low.

The most important aspect of an LED driver chip is the amount of current it has to sink. Many LED applications call for a current sink specification of 5 to 15 mA. Because the supported Altera devices can sink up to 50 mA per pin, these devices can directly integrate commercial current-sinking LED driver chips.

**Table 2: Maximum Sink Current for the Supported Altera Devices**

Device	Maximum Sink Current Per Pin (mA)
MAX II	25 <sup>(1)</sup>
MAX V	25 <sup>(1)</sup>
MAX 10	25 <sup>(1)</sup>
MAX 3000A	25
MAX 7000A/AE	25
MAX 7000B	50
MAX 7000S	25

Although a single pin from a MAX 7000B device can sink up to 50 mA of DC current, each GNDIO group can concurrently sink up to 200 mA of current due to the support of advanced I/O standards.

<sup>(1)</sup> 25 mA is the absolute maximum rating for the sink current per pin in the MAX II, MAX V, and MAX 10 devices. Device operation at the absolute maximum ratings for extended periods of time may have adverse effects on the device.

**Table 3: Maximum Source Current for Each VCCIO Group and Maximum Sink Current for Each GNDIO Group in the Supported Altera Devices**

Device	Maximum Source Current Per VCCIO Group (mA)	Maximum Sink Current Per GNDIO Group (mA)
MAX II	170	130
MAX V	170	130
MAX 3000A	224	167
MAX 7000A/AE	224	167
MAX 7000B	380	200
MAX 7000S	244	160

For example, the EPM240 device has six GNDIO pads, which provide six I/O regions that can sink up to 130 mA. If you need to sink 15 mA for the outputs, you can have eight outputs per region. With the six regions of I/O between GNDIO pads, there are 48 possible outputs, each sinking 15 mA.

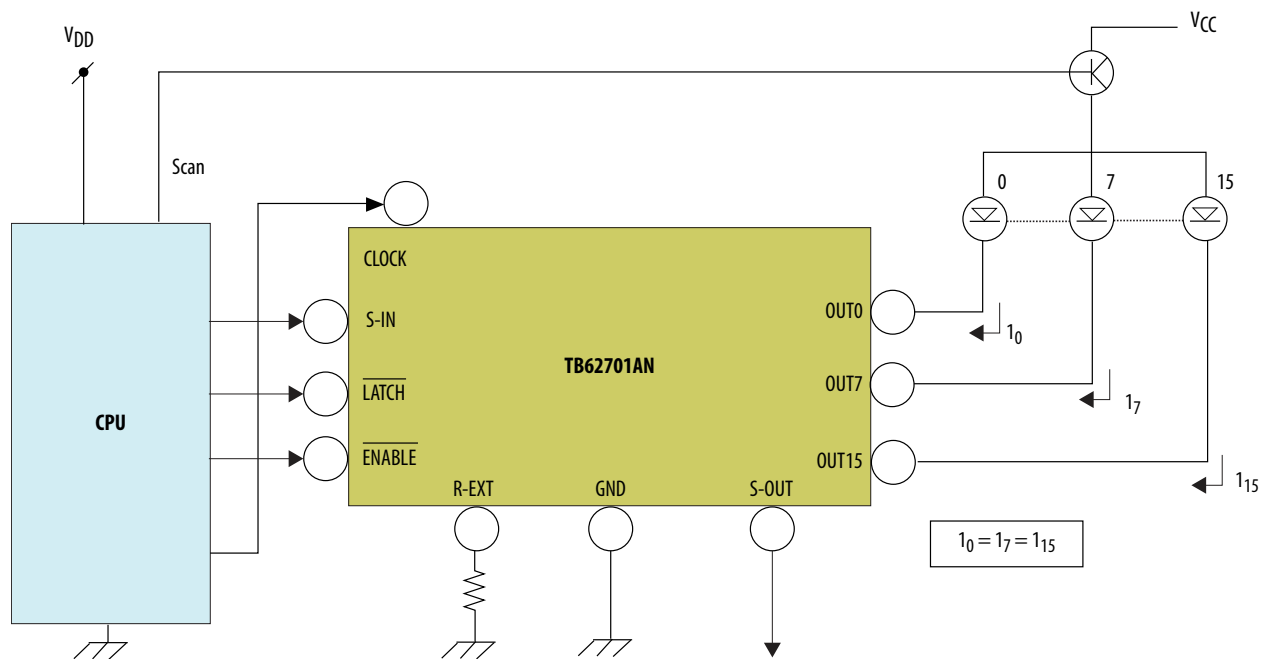
#### Related Information

- [MAX 3000A Programmable Logic Device Family Datasheet](#)
- [MAX 7000A Programmable Logic Device Datasheet](#)
- [MAX 7000B Programmable Logic Device Datasheet](#)
- [DC and Switching Characteristics for MAX II Devices](#)
- [DC and Switching Characteristics for MAX V Devices](#)
- [MAX 10 FPGA Device Datasheet](#)
- [MAX 3000A Device Pin-Out Files](#)
- [MAX 7000, MAX 7000A & MAX 7000B Device Pin-Out Files](#)
- [MAX II Device Pin-Out Files](#)
- [MAX V Device Pin-Out Files](#)
- [MAX 10 Device Pin-Out Files](#)

## Implementing LED Driver Chips

The following figure shows an example of an application circuit with the Toshiba TB62701AN LED, its 16-bit constant current LED driver with shift registers and latch functions. The 16 outputs of the circuit sink current for two seven-segment displays. You can implement the LED driver chip in the circuitry using only one of the supported Altera device, provided the device has enough register and pin capabilities to replace the functionality of the entire LED driver chip.

Figure 1: Application Circuit Example Using the Toshiba TB62701AN LED Driver Chip

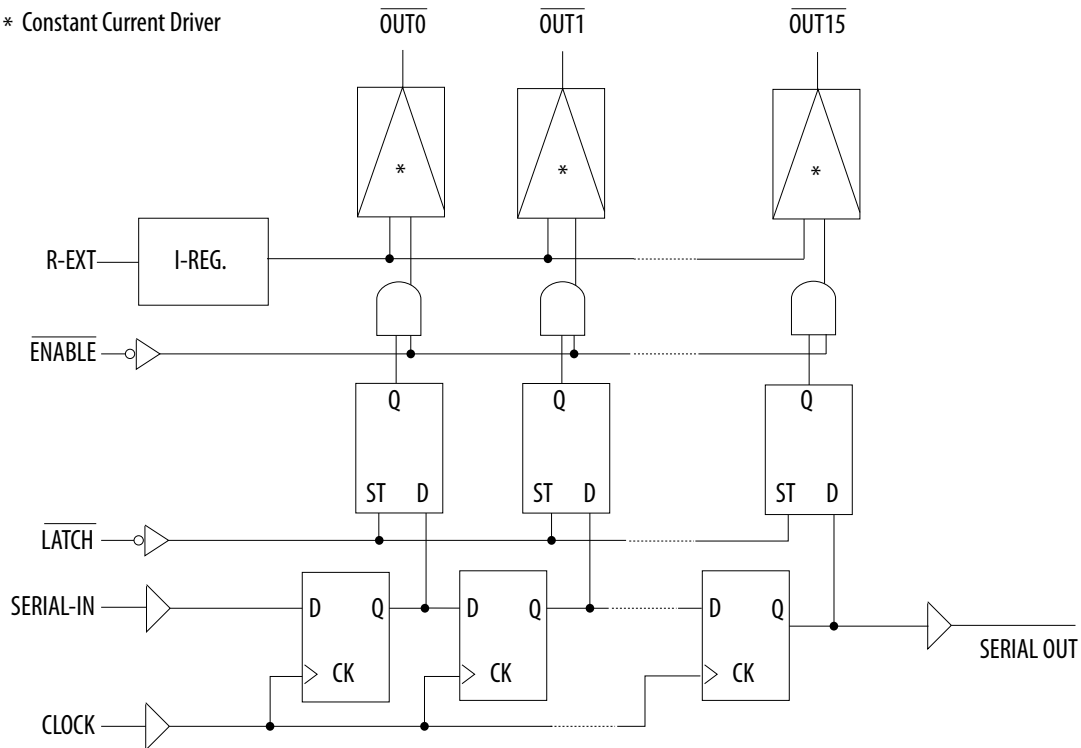


The following figure shows a block diagram of the Toshiba TB62701AN LED driver chip. The Altera LED driver reference design has the same architecture as the TB62701AN. It consists of three main categories:

- 16-bit serial shift registers
- 16-bit latches
- An array of AND gates

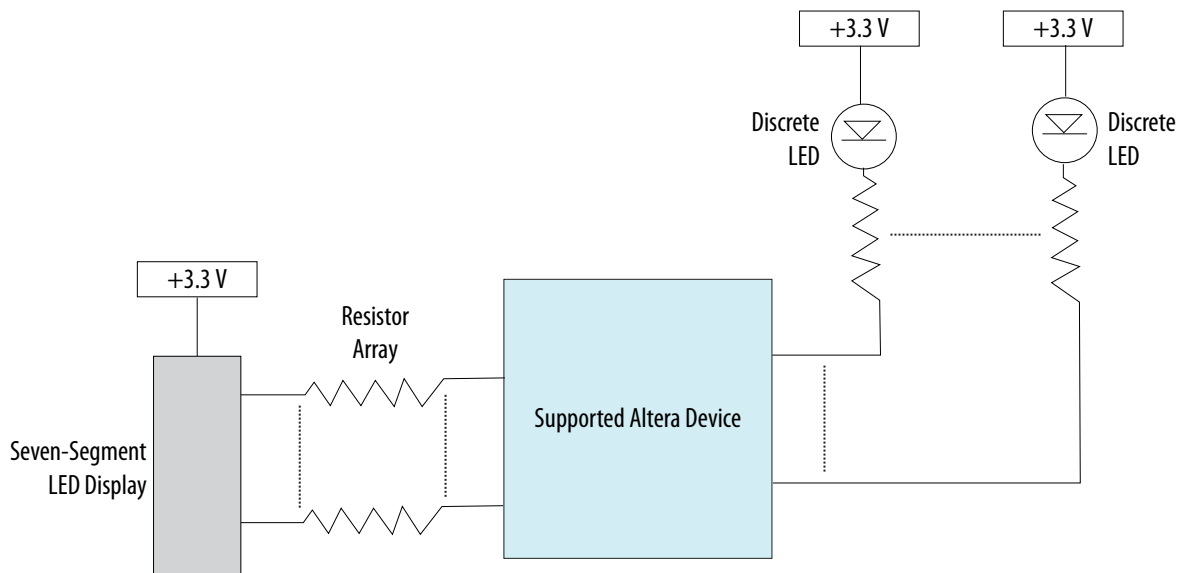
The data from serial-in that determines which LED to be driven is shifted serially into the 16-bit shift registers for every low-to-high transition on the clock signal. With a high-to-low transition on the latch signal, the 16-bit data, which stores the 16-bit shift registers, is latched into 16-bit latches to drive the LED when the enable signals drive low.

Figure 2: Block Diagram of the Toshiba TB62701AN LED Driver Chip



The Altera LED driver reference design only emulates the functioning of the Toshiba TB62701AN. To implement the external resistor ( $R_{EXT}$ ) and the current-regulating circuit, place an individual current-limiting resistor between the cathode side of the LEDs diodes and the I/O pins of the supported Altera device.

Figure 3: Implementing the LED Driver Using a Supported Altera Device



The right hand side of the figure above shows the connection between discrete LEDs and the I/O pins of a supported Altera device, while the left hand side shows the connection between a seven-segment LED and the supported Altera device. The output pins of the supported Altera device connected to the LEDs are driven low to turn on the LEDs.

## Design Implementation

The detailed description of the implementation is based on the MAX 10, MAX II, and MAX 3000A devices. This application can also be implemented in MAX V, MAX 7000A, MAX 7000B, and MAX 7000S devices.

You can target the LED drivers reference design in MAX 10 (10M08SAE144C8G), MAX II (EPM240T100C3), or MAX 3000A (EPM3064ATC44) devices using the Quartus® II software.

**Table 4: 10M08SAE144C8G LED Drivers Design Utilization**

Resource	Available	Used	Utilization (%)
Logic Elements	8,064	33	<1
Registers	8,064	17	<1
I/O pins	103	21	20

**Table 5: EPM240T100C3 LED Drivers Design Utilization**

Resource	Available	Used	Utilization (%)
Logic Cells	240	33	1
Flips Flops	240	17	1
I/O pins	65	21	32

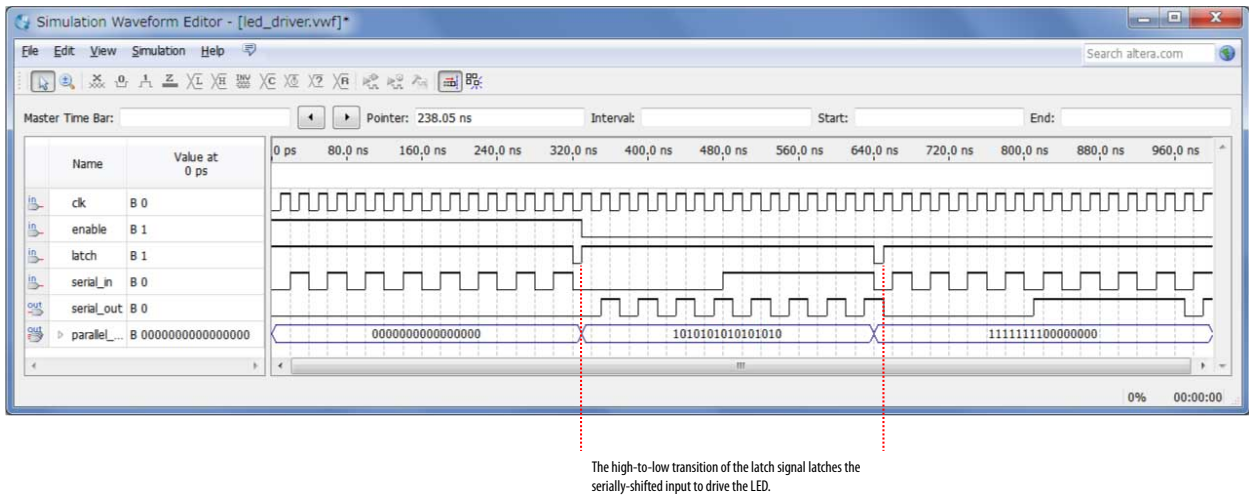
**Table 6: EPM3064ATC44 LED Drivers Design Utilization**

Resource	Available	Used	Utilization (%)
Macrocells	64	49	76
Flips Flops	64	17	26
I/O pins	34	21	61

## Design Verification

You can achieve design verification for the LED driver by using the Quartus II software. MAX II and MAX 3000A design verification occurs in both functional and timing simulations.

Figure 4: LED Driver Timing Simulation in the Quartus II Software



The LED driver is first configured so that the `parallel_out` drives an output value of 1010101010101010. In the final configuration, the `parallel_out` output value is 1111111100000000.

## Document Revision History

Date	Version	Changes
September 2014	2014.09.22	Added MAX V and MAX 10 devices.
October 2008	2.3	Added note to Table 2.