

## Introduction

Low-Power HCSL (LP-HCSL) was developed to lower the power consumption of traditional HCSL drivers. Other major advantages of LP-HCSL were soon discovered, including better performance driving long traces, easy AC-coupling, reduced board area, easier board routing and Bill of Material (BOM) reduction. These advantages will be discussed in this application note. It is important to note that an HCSL receiver cannot tell the difference between a traditional HCSL driver and a LP-HCSL driver.

IDT has been awarded patents US 7342420 B2, US 7821297 B2 and US 7830177 B2 for this technology.

## Functionality

Traditional HCSL outputs steer a constant 15mA current between true and complement outputs of a differential pair. This results in a continuous power consumption of ~50mW from 3.3V for each differential HCSL output pair.

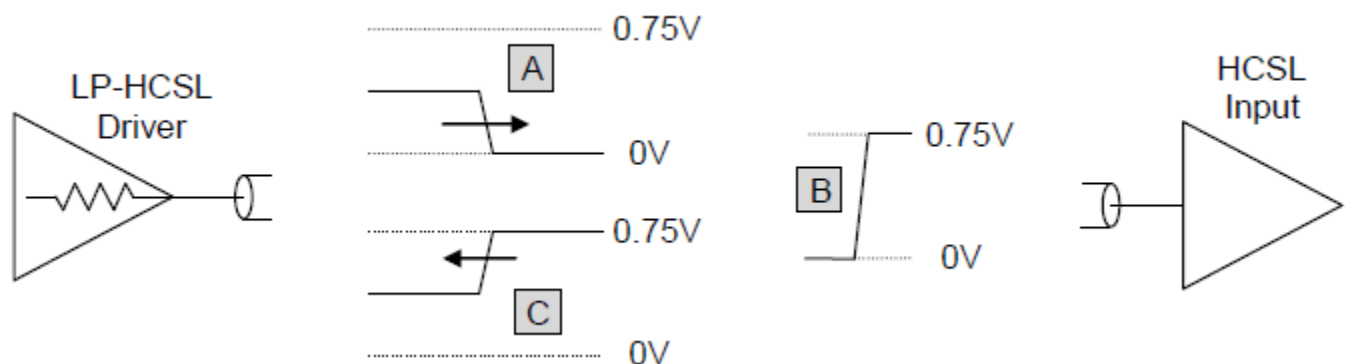
Low Power HCSL uses a push-pull voltage drive as opposed to current drive with traditional HCSL. This results in a current consumption of approximately 4 to 5mA. Supply current flows in the driver only during the time a rising edge is traveling from the driver to the end target and then back to the driver (round trip flight time).

When an output pin moves from 0V to 0.75V the 50Ω output impedance is in series with the 50Ω PCB trace impedance and a current of  $0.75/(50+50)=0.0075\text{A}$  or 7.5mA starts flowing out of the output pin. The voltage on the PCB trace is 0.375V and this half high edge travels towards the target (see Figure 1, A). The target impedance is high, so when the rising edge arrives at the target, it rises up twice as high as 0.375V. So, the target input receives a 0.75V rising edge (see Figure 1, B).

At the target the rising edge reflects as another 0.375V edge on top of the 0.375V level already on the trace and travels back to the driver (see Figure 1, C).

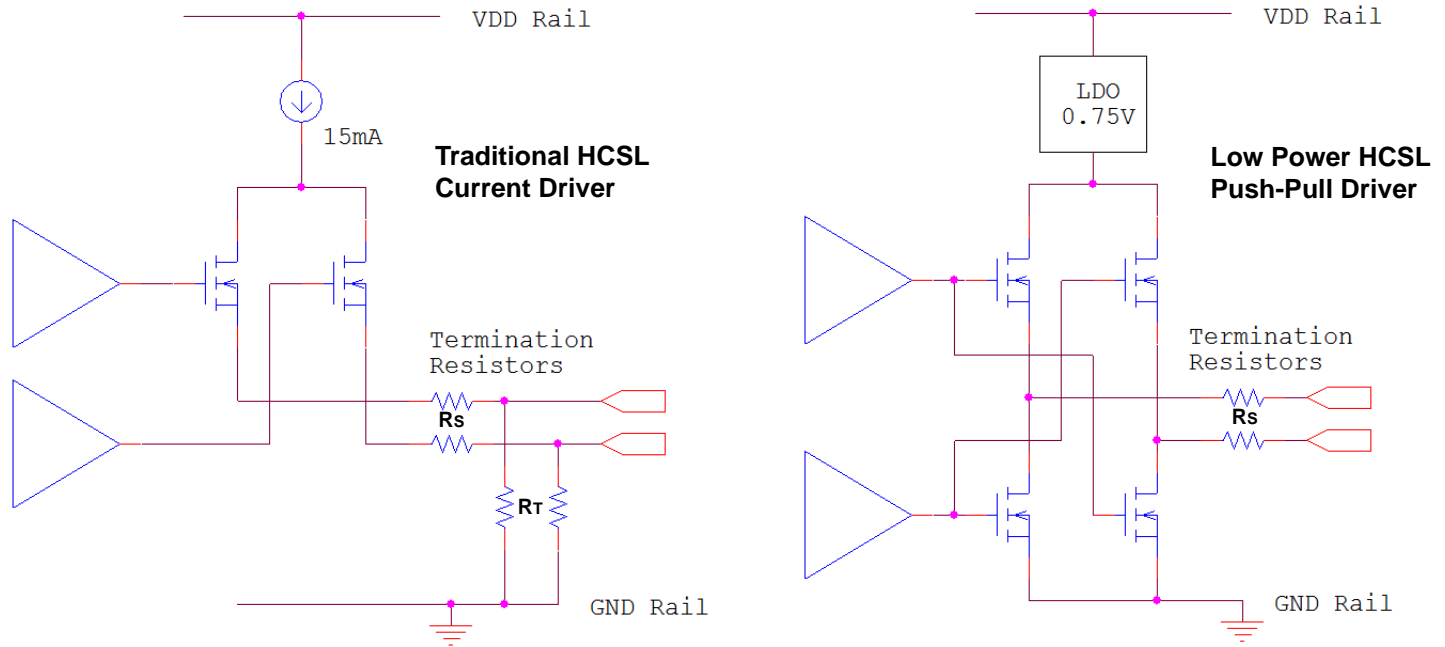
When this edge arrives at the driver, it encounters 50Ω termination and is absorbed. Since the PCB trace voltage is now 0.75V at both the driver and receiver sides of the PCB trace, there will be no more current flowing in the driver output pin. So, the 7.5mA of current only flows for the time it takes for the rising edge to travel from the driver to the target and back. For a 10 inch trace, it takes a rising edge about 2.5ns to travel back and forth. This is only 25% of the total 100MHz cycle so the average current consumption per pin is  $7.5\text{mA} / 4 = 1.9\text{mA}$ . For both pins of a differential output it then takes 3.8mA to drive a 10 inch differential trace. Adding switching and parasitic losses, the total current per LP-HCSL output pair is about 4mA to 5mA when driving a 10 inch trace.

Figure 1. Rising Edge Traveling Up and Down the PCB Trace



## HCSL Driver Topology

Figure 2. Comparing Traditional and Low-Power HCSL Driver Topology



## Advantages of LP-HCSL

### 1) 3x to 9x Lower Power Consumption

We have already seen that the LP-HCSL driver uses 1/3 the current of the traditional HCSL driver (5mA versus 15mA). From Figure 2, we see that the 15mA current source is supplied by the VDD rail of the traditional HCSL device. Practical considerations limit the lower limit of this power rail to 2.5V. The LDO used in the LP-HCSL driver can be powered from any voltage from VDD down to the output voltage + LDO headroom (or 800mV + 250mV = 1.05V). If the traditional HCSL output power supply is 3.3V and the LP-HCSL power supply is 1.05V, we see a 3x reduction in power supply voltage. With 1/3 the current and 1/3 the voltage rail, LP-HCSL can achieve a 9x reduction in power.

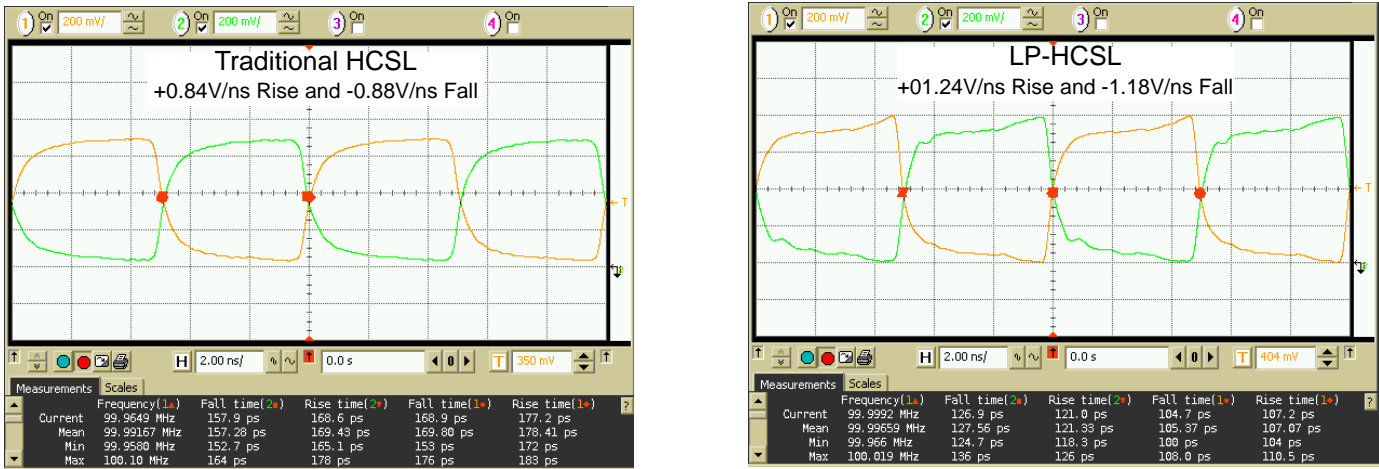
LP-HCSL outputs also allow the output amplitude to be adjusted (up or down) by adjusting the LDO setting. Many IDT LP-HCSL devices allow amplitude adjustment via SMBus registers.

### 2) Better Drive of Long Traces

PCIe clocks are specified to have slew rates of 0.6V/ns to 4.0V/ns. LP-HCSL outputs provide higher slew rates when driving long traces. A traditional HCSL driver depends upon the external 50Ω termination to make the falling edge of the clock. This makes rise/fall matching more difficult, since only the rising edge of the clock is under control of the traditional HCSL output. The LP-HCSL output controls both the rising and falling edge of the clock. The faster slew rates of LP-HCSL are especially important when driving long PCB traces and/or passing through connectors to other PCBs in the system. Faster slew rates at the start of a long trace will result in faster slew rates at the end of long traces. Faster slew rates at a receiver translate into lower jitter and lower bit error rates.

IDT used a Nelco test board to compare the slew rate of traditional HCSL and LP-HCSL after driving 30-inch traces. From Figure 3, we see that LP-HCSL was observed to be almost 50% faster than traditional HCSL at the end of a 30 inch long trace.

Figure 3. After Passing Through 30 inch Long PCB Trace



Yellow and Green are the true and complementary outputs on the differential output pair. The slew rates are measured in +/-75mV window around the crossing point.

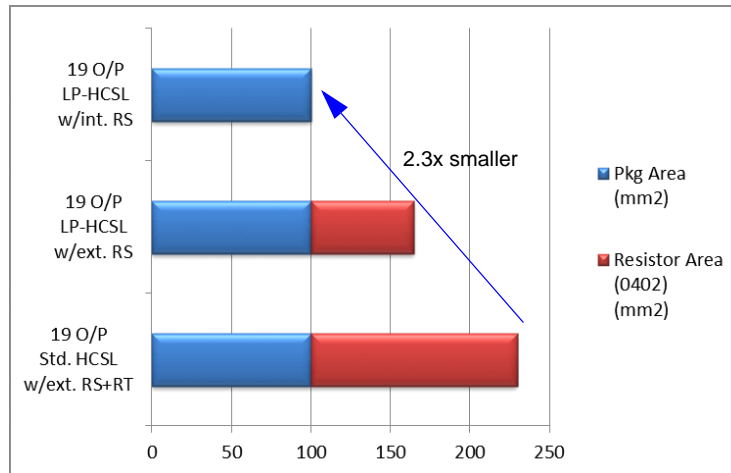
3) Easy AC-Coupling

LP-HCSL does not require a DC coupled termination like traditional HCSL does. You can add capacitors in series with LP-HCSL signals without affecting the signal swing or termination properties. With traditional HCSL care has to be taken that a DC path to ground remains when adding AC coupling and this may require extra components.

4) Smaller Board Area, Easier Board Routing and Reduced Bill of Materials

LP-HCSL outputs do not need the termination resistor to ground. This saves 2 of the 4 termination resistors required by a standard HCSL differential output. IDT also integrates the series termination in some of its LP-HCSL drivers, eliminating all 4 termination resistors, so all that is required is a PCB trace between the driver output and the target input. Power dissipation in the termination resistors prevents their integration in traditional HCSL drivers, especially with a large amount of outputs on one die.

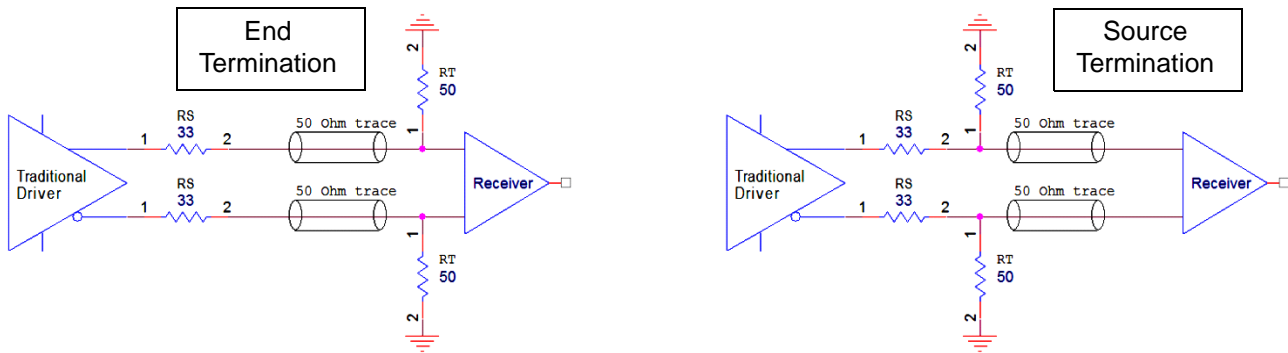
Figure 4. Board Area Savings with LP-HCSL



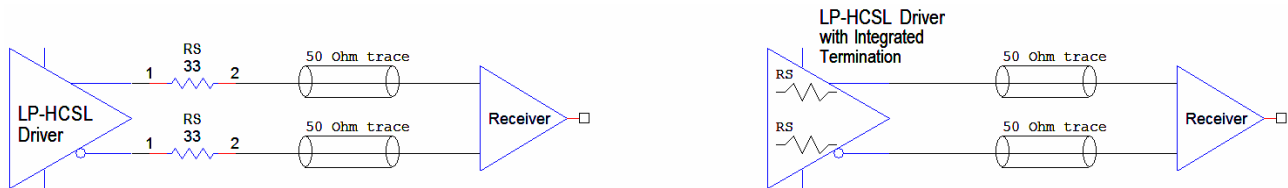
Traditional HCSL termination uses a 50Ω resistor to ground at the end of the PCB trace. Later, another method was introduced, placing the 50Ω to ground near the driver. This is called “Source Termination” and allows for the clock to pass through connectors that can be unplugged while the circuit is active (hot swapping). LP-HCSL has its termination at the driver side by definition, and it can work with end terminations. This setup is referred to as double termination (more on this in a moment). Source termination versus end termination makes no difference to the receiver.

**Figure 5. Traditional HCSL Termination**

The series resistors RS are needed to avoid excessive ringing.



**Figure 6. LP-HCSL Termination**



The termination resistors (RS) are now in series with the clock line, near the driver. The driver itself is designed to have 17Ω output impedance so it requires another 33Ω to match 50Ω PCB traces. The schematic on the right has the termination resistors integrated so no external components are needed to drive 50Ω PCB traces.

Traditional HCSL doesn't use the driver itself as part of the termination. Besides the 50Ω termination resistor, traditional HCSL needs an additional 33Ω series resistor to avoid a reflection and ringing between the driver and the 50Ω terminated trace. The LP-HCSL concept combines the main termination and ringing avoidance in the same 33Ω series resistor, reducing the parts count.

Certain applications use 85Ω differential traces (or 42.5Ω single ended). For these applications, we recommend RS=27Ω. IDT also offers clocks with the 27Ω RS integrated for 85Ω systems.

**Double Termination:** Certain receivers may have a 100Ω differential termination resistor in the chip. These receivers are usually more generic, can handle a wide range of amplitudes and common-mode voltages, and may require AC coupling of the clock signals. LP-HCSL drivers can readily drive double terminations. Having termination resistors at both the source and receiver lowers the amplitude to about 400mVpp at each pin (800mVpp differential). Usually it is not a problem for this type receiver to work with the smaller amplitudes. The 400mVpp (800mVpp differential) level even exceeds the 150mVpp (300mVpp differential) input swing spec for PCIe reference clocks.

## Conclusion

Low Power HCSL not only reduces power significantly, it also better drives long traces, saves board area, reduces BOM costs, and more easily drives AC-coupled transmission lines. This makes Low Power HCSL the choice for future designs.

**Table 1: Traditional HCSL versus Low Power HCSL Overview**

	Traditional HCSL	LP-HCSL
Power Supply Current per driver	15mA	4 ~ 5mA
Available output driver VDD voltages	Down to 2.5V	Down to 1.05V
Slew Rate after 30" PCB trace	0.8V/ns	1.2V/ns
Passives required per differential output	4 resistors	None for integrated termination



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(Rev. 4.0-2 April 2020)

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