

# Why You Should ‘Switch’ to CBT Bus Switches



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Switches are one of the most common electrical circuit components today. An ideal switch should have zero resistance when on and infinite resistance when off. The signal must pass through the switch without any distortion when enabled and should be completely isolated when off. In the real world, however, the on-state resistance will be minimal and the off state will have high resistance.

## Cross Bar Technology Switches

TI’s cross bar technology (CBT) switches are part of TI’s original bus switch family, designed with simple FETs at their core, as shown in [Figure 1](#). A and B terminals are bidirectional I/Os and are interchangeable as drain or source once enabled. The on-state resistance,  $R_{ON}$ , is nonlinear once  $V_{I/O}$  approaches  $V_{CC}$ .

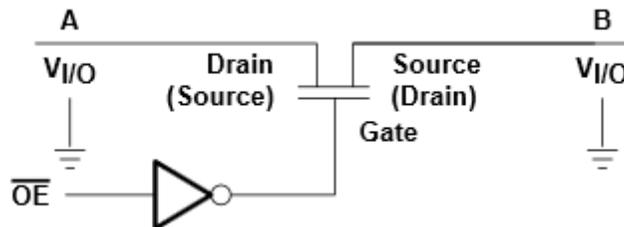


Figure 1. CBT Functional Diagram

## Low-voltage Cross Bar Bilateral Switches

Low-voltage CBT (CBTLV) bilateral switches have single P- and N-channel transistors, as shown in [Figure 2](#). The  $R_{ON}$  is flatter due to the parallel combination of both NFET and PFET.

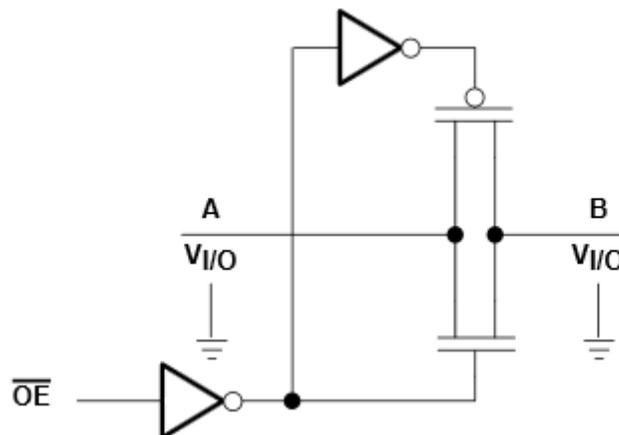
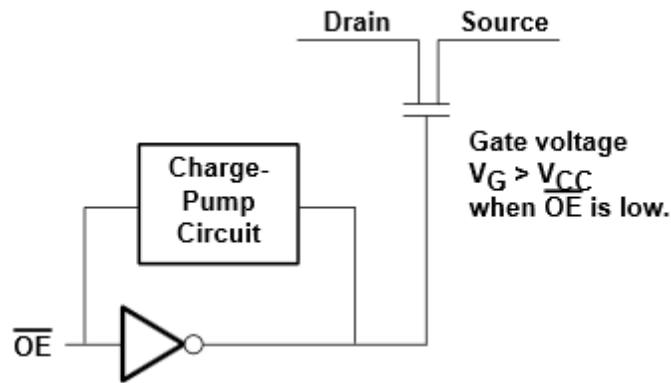


Figure 2. CBTLV Functional Diagram

## High-bandwidth Cross Bar Switches

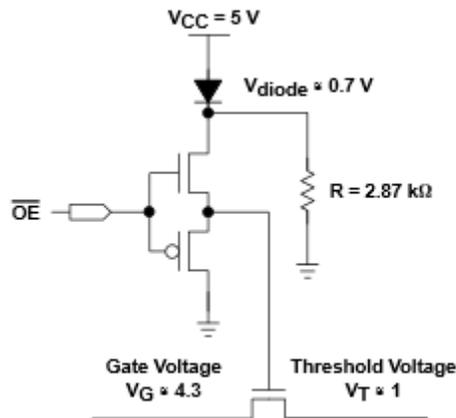
High-bandwidth cross bar (CB3Q) switches have an internal charge pump that boosts the gate voltage beyond rail, enabling a low flat  $R_{ON}$  across the voltage range – but at the expense of higher  $I_{CC}$ , as shown in [Figure 3](#).



**Figure 3. CB3Q Featuring Charge-pump Circuitry**

### Cross Bar Translating Switches versus Cross Bar Technology with Diode Switches

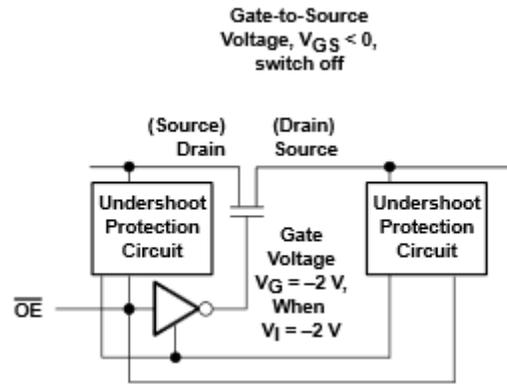
Cross bar translating (CB3T) switches and cross bar technology with diode (CBTD) switches have translating features. CB3T switches have an internal control circuitry that enables a high-to-low translation feature on their inputs to outputs. CBTD switches feature an internal diode that drops the operating rail for the enable pin and also allows high-to-low translation, as shown in [Figure 4](#).



**Figure 4. CBTD with Internal Diode**

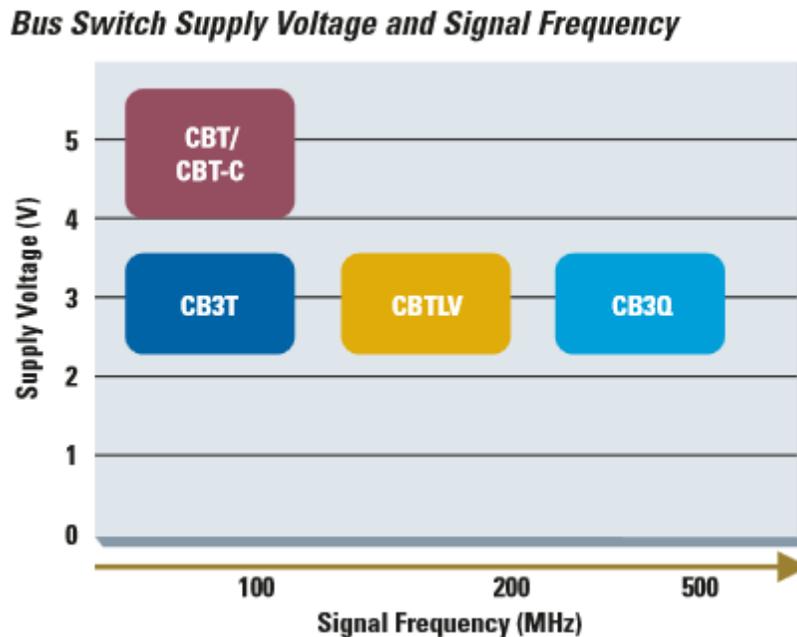
### Comparing Cross Bar Bus Switches

CBT-C (clamp), CBTK (active clamp) and CBTS (Schottky) switches have -2V undershoot protection circuitry that inhibits the N-channel metal-oxide semiconductor (NMOS) transistor from turning on when the switch is off, as you can see in [Figure 5](#). The gate is biased to the same negative voltage when the input has an undershoot.



**Figure 5. CBT-C with Undershoot Protection**

Comparing bandwidth operation, the CB3Q with the charge pump has up to 500MHz, which is highest among all of the switches. CBT/CB3T switches have up to 100MHz bandwidth, which is shown in [Figure 6](#).



**Figure 6. Bandwidth vs.  $v_{CC}$  Comparison**

Note the  $R_{ON}$  comparison in [Figure 7](#). CBT switches with the NMOS pass transistor have lower  $R_{ON}$  resistance until  $V_{IN}$  reaches about 3V, beyond which the resistance increases sharply when the NMOS starts to switch off. CBTLV switches have flat  $R_{ON}$  due to the parallel combination of NMOS and PMOS. The CB3Q has low flat  $R_{ON}$  across a wider input-voltage range of interest, due to higher gate voltage from the charge pump.

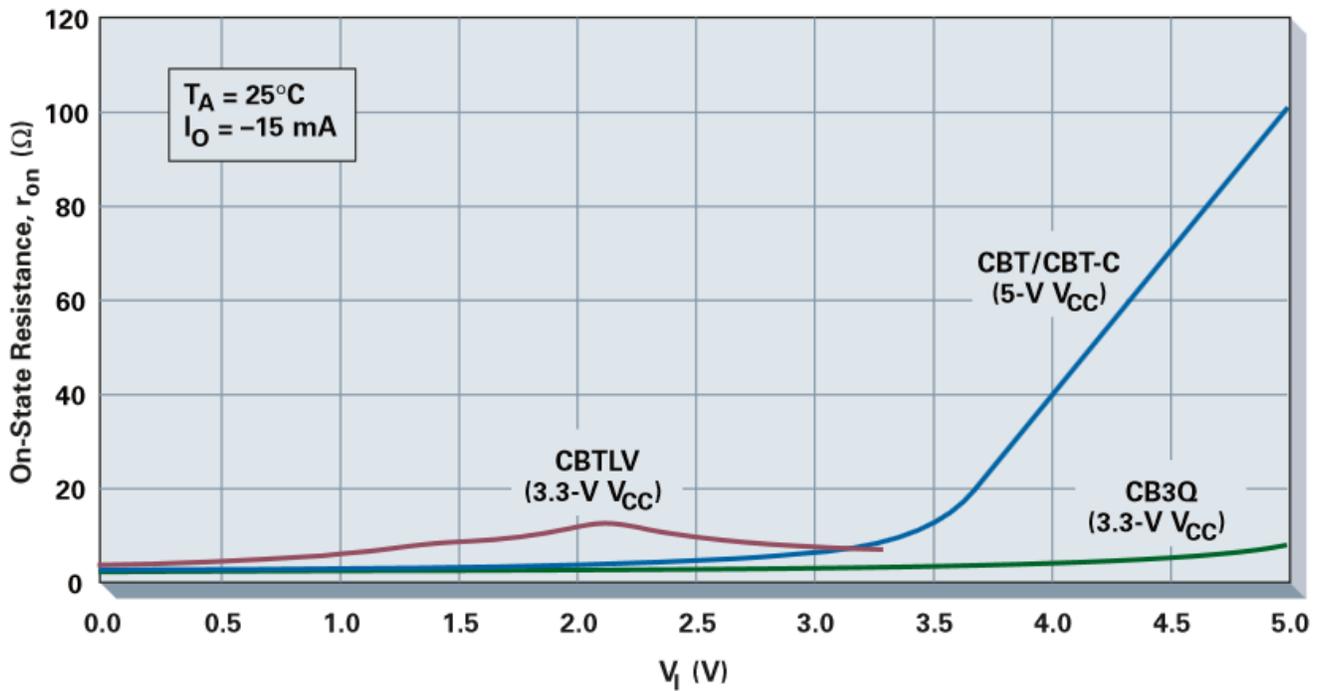


Figure 7. Comparison of  $R_{ON}$

Figure 8 illustrates the output behavior of each of the switches for different input signals and at different operating  $V_{CC}$  levels. Note the beyond-rail feature of CB3Q, the rail to rail of CBTLV, the below rail of CBT/CBT-C and the translation feature of CB3T.

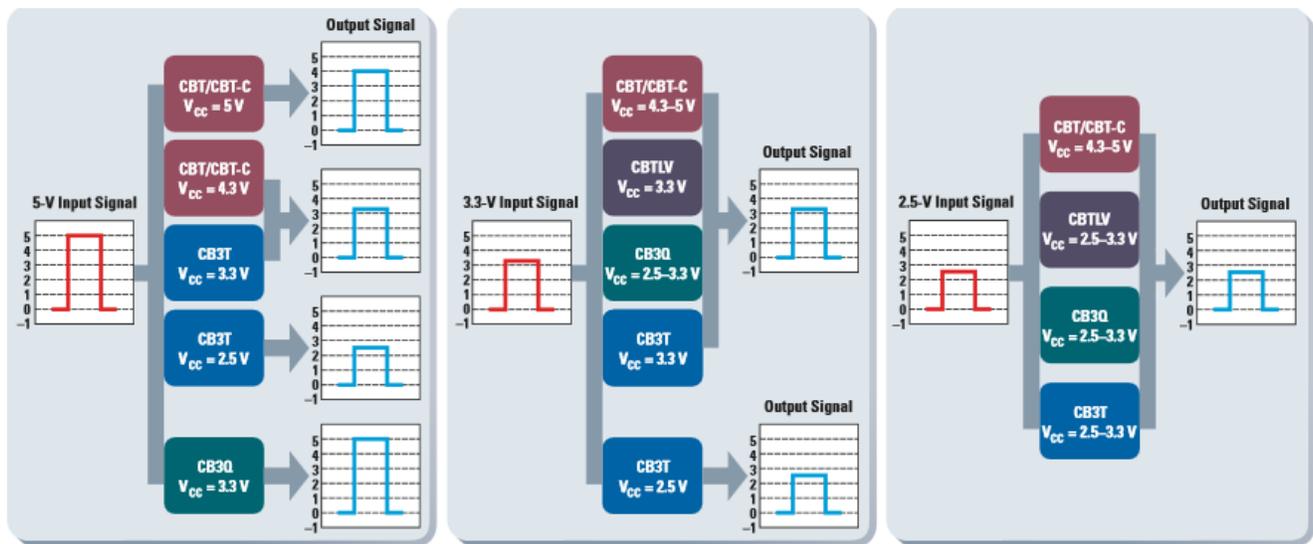


Figure 8. I/O Signaling Capabilities of the CBT Family

The presence of  $I_{OFF}$  protection circuitry and output enable can make these switches attractive for the live-insertion scenarios in servers and backplanes. When powered off, the switches can isolate systems with active I/Os on them. Using the output enable control, you can achieve isolation during power ramp-up and ramp-down. CB3Q switches are beneficial for high-speed, high-bandwidth applications like USB multiplexing.

I will be talking more about  $I_{OFF}$  protection circuitry and specifications in an upcoming blog post, however, in the meantime, please leave a comment below and let me know your experience with the CBT family. The characteristics and features of CBT switches described here makes them suitable for different applications across the industry.

**Additional Resources**

- Read the application note, [“Selecting the Right Texas Instruments Signal Switch.”](#)
- Download the [“Digital Bus Switch Selection Guide.”](#)
- Read the application note, [“CBT-C, CB3T and CB3Q Signal-Switch Families.”](#)
- Visit the [TI E2E™ Community Voltage Translation/Level Shifters forum](#) to find answers from TI’s logic and voltage translation team and fellow engineers.

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