TMDS Clock Detection Solution in HDMI® Sink Applications TS3USB3031, SN65LVDS4, SN65LVDS17

Gibson Kim

ABSTRACT

High-Definition Multimedia Interface (HDMI®) sink applications such as digital TVs, monitors, and other display equipment are able to wake up from standby or sleep mode by detecting *Transition-Minimized Differential Signaling* (TMDS) clock or signals in HDMI applications.

Contents

List of Figures

List of Tables

Trademarks

Blu-ray Disk is a trademark of Blu-ray Disc Association.
HDMI is a registered trademark of HDMI Licensing, LLC.
All other trademarks are the property of their respective owners.

1 Waking Up an HDMI Sink Device

HDMI is a defacto interface standard in consumer electronics and the most successful and easiest video and audio connector in the industry. Most digital TVs, monitors, and video display equipment have one or more HDMI ports. Video source equipment such as set-top boxes, gaming consoles, Blu-ray Disk™ players, notebooks, and mobile video sources support HDMI as well.

HDMI supports a supplemental specification, *Consumer Electronics Control* (CEC), to control the HDMI source and sink in HDMI-connected equipment. CEC provides the same 'language' between the HDMI equipment allowing users to easily control them. Figure 1 shows the high-level HDMI interconnection, including a CEC line.

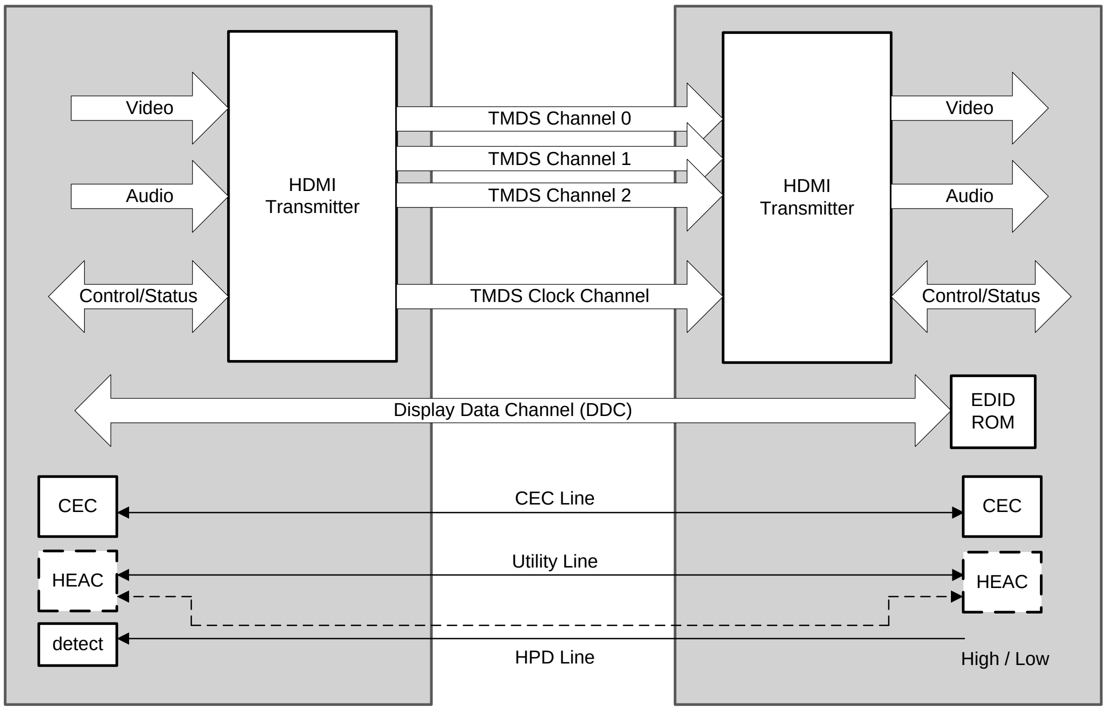


Figure 1. HDMI High-Level Block Diagram

CEC is one of the 19 HDMI connector pins and CEC has its own electrical and protocol specification. A number of different messages and operation code (opcode) are used for the best user experience so that users can use only one remote controller to control both HDMI source and HDMI sink devices. For instance, if an HDMI source and sink are in standby mode and the user wants to wake up both of them, the following power-on function code can be used to switch on the HDMI devices by pressing the power button on the remote controller. This will wake up both the HDMI source and sink devices. More advanced user-controlled CEC messages are available, refer to the CEC specification in HDMI 2.0, or older version specifications.

Table 1. CEC Operation Codes

UI Command Code	User Operation	Function
0x6C	Power off function	Puts the device into the Standby state. If repeated, the device stays in the Standby state.
0x6D	Power on function	Puts the device into the On (non-Standby) state. If repeated, the device stays in the active state.

1.1 Reasons for Wake Up Failure

Although CEC is provided for the control of the HDMI devices, its implementation and operation is not that simple. It is common that HDMI sink users experience the HDMI source is not controllable through a single remote controller as expected, and vice versa. This is because many HDMI sources and sinks do not support CEC, including a few very well-known HDMI source devices and thus there is no simple way to control both the HDMI source and sink devices at once. There are also a number of HDMI devices supporting CEC, but require complicated steps to enable the feature in the equipment. Not as common are some devices that implement vendor-specific codes preventing HDMI source and sink devices from communicating.

2 Communicating Without CEC

This section provides examples for making the HDMI sink device detect *Transition Minimized Differential Signaling* (TMDS) clock or signal from an HDMI source device so that the HDMI sink can wake up from its standby state by turning on the HDMI source with a single remote controller.

The HDMI transmitter source detects receiver terminations in HDMI sink. If the HDMI receiver enables the termination resistors, then the transmitter will determine the 3.3-V terminated level and that the receiver is connected and functioning.

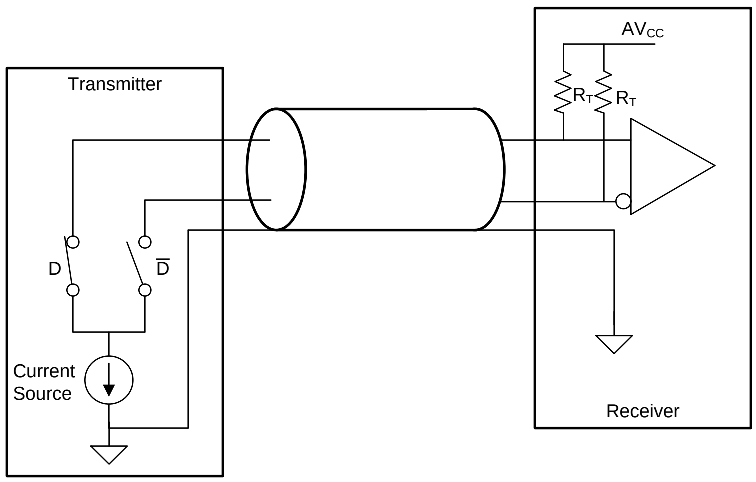


Figure 2. Conceptional Schematic for one TMDS Differential Pair

Table 2. Termination Requirement in HDMI Receiver

Item	Value
Termination supply voltage, AV_{CC}	3.3 V ±5%
Termination resistance, R_T	50 Ω ±5%

When an HDMI sink is in standby mode, most HDMI sinks will disable the termination resistors to save power while enabling a *Hot-Plug Detection* (HPD) signal (high) as long as an HDMI source plug is providing HDMI 5 V. The HDMI source will have no way to provide a TMDS signal and wake up the sink, because they are not terminated.

2.1 Implementation Example 1: TS3USB3031, SN65LVDS4

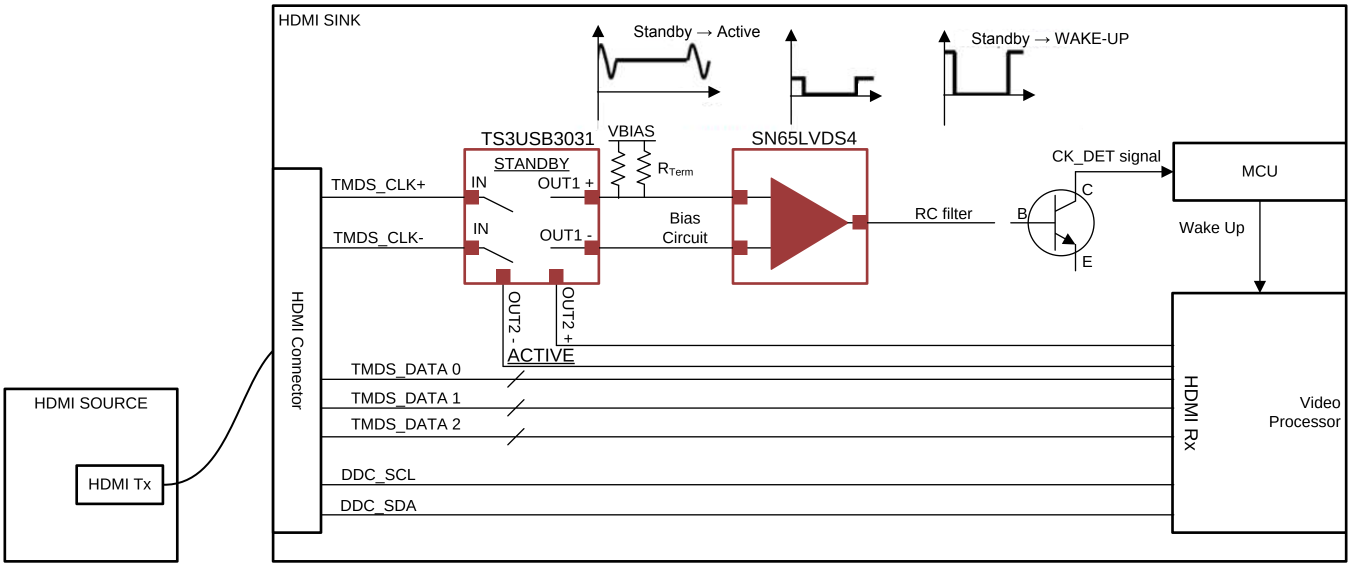


Figure 3. Implementation Example Block Diagram 1

This is proven by simulation and actual test board environment for both functionality and HDMI compliance test at different corner cases:

- A high-speed switch can be used to switch or isolate actual TMDS clock path from TMDS clock detection path. In *Active* mode, TMDS clock can be connected to HDMI Rx in a video processor. In Standby mode, it is directed to TMDS clock and signal detection circuitry to check if there is an incoming signal or not.
- Use caution when selecting a high-speed switch. In order to fulfill signal integrity and HDMI compliance test, the electrical characteristics of the switch are important. The TS3USB3031 provides a good enough bandwidth and I/O capacitance up to 4K/60fps video conditions. A good layout technique is required to minimize impact to the impedance - HDMI spec: 100 Ω ±15% with single excursion of 100 Ω ±25% with duration less than 250 ps.
- Proper termination for HDMI source to see R_{Term} in the standby mode of the HDMI sink is needed.
- Differential to single-ended receiver can be used to convert TMDS clock signals to single-ended TTL or CMOS signals. A proper bias circuitry may be needed for TMDS to the Differential to single-ended receiver. The SN65LVDS4 has a wide-enough bandwidth, V_{ID} and sensitivity spec so that TMDS clock rates from all video resolutions can be converted to single-ended signal.
- Depending on the MCU or processor that will detect the wake-up signal from SN65LVDS4, a proper RC filtering may be needed to eventually detect the wake-up signal. If the MCU or processor can detect the clock signal itself, this step is not needed.
- A proper transistor may be used to meet I/O spec of the MCU.
- Once the wake-up signal is detected, then the MCU wakes up the video processor and the video processor can enable R_{Term} in HDMI Rx for normal operation.

2.2 Implementation Example 2: SN65LVDS17

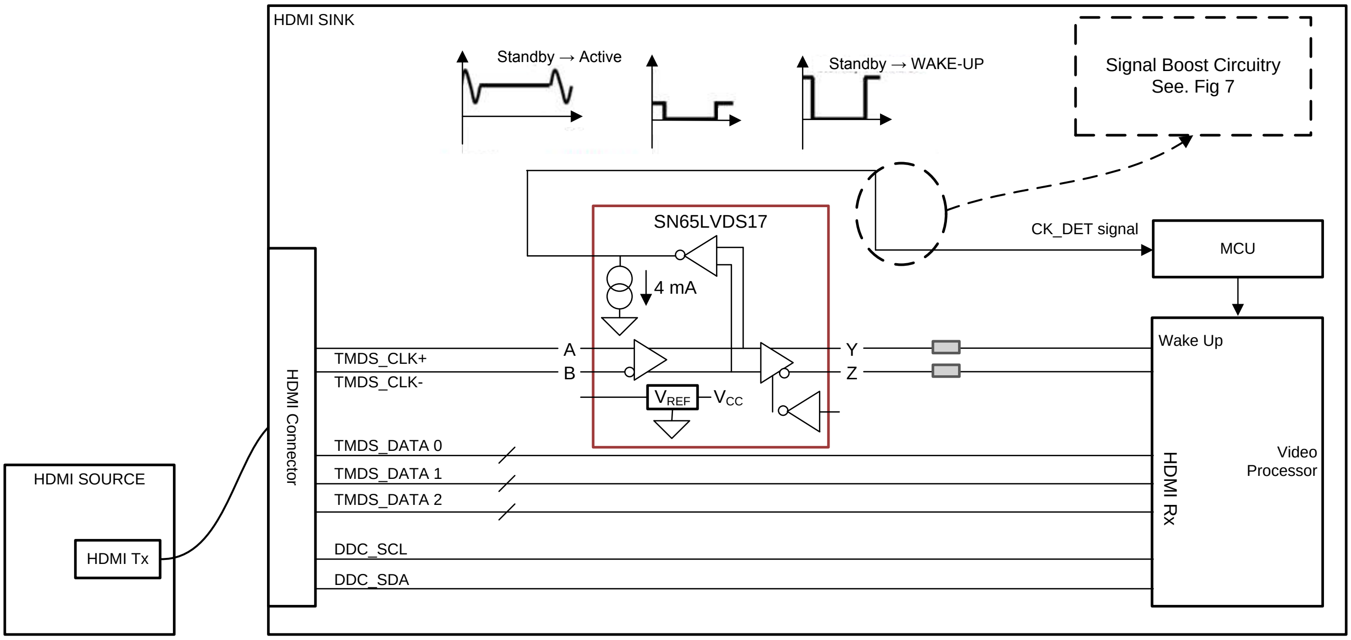


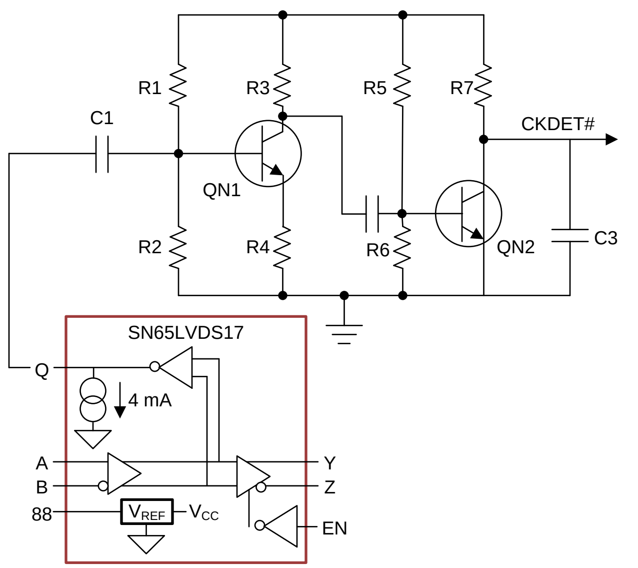
Figure 4. Implementation Example Block Diagram 2 - Single-Chip Implementation

This is proven by simulation and actual test board environment for both functionality and HDMI compliance test at different corner cases.

- Products like the SN65LVDS17 can be used to detect TMDS clock. SN65LVDS17 supports wide enough bandwidth up to 2 GHz for TMDS clock. It senses clock signals and transmits Q output with 575-mV peak-to-peak output voltage.
- Proper termination for HDMI source to see R_{Term} in standby mode of HDMI Sink is needed. AC coupling caps are required between SN65LVDS17 to HDMI Rx.
- Depending on the MCU or processor that will detect the wake-up signal from SN65LVDS17, a proper circuitry at Q output may be needed to eventually detect the wake-up signal. If the MCU or processor can detect the Q signal of the SN65LVDS17 itself, this step is not needed.
- Once the wake-up signal is detected, then the MCU wakes up the video processor and the video processor can enable R_{Term} in HDMI Rx for normal operation.

The following list is a circuit suggestion to boost up Q output from SN65LVDS17 and to provide a proper clock detection signal to the MCU. It is required to have transistors with enough bandwidth and accurate pull up and pull down the design (R5 and R6) depending on the transistor (QN2).

- C1 allows decoupling of the LVDS17 output bias to avoid issues from part-to-part variations
- R1 and R2 to bias QN1
- QN1 has to have enough BW to pass a maximum of 340-MHz signals
- R3 and R4 provide gain
- C2 and R5 ensure QN2 is always off and no leakage occurs when there is no clock signal
- QN2 has to have enough BW to pass 340-MHz signals
- R6 and C3 determine how fast the circuit will determine clock presence or absence
- MMBT5179 or similar performance transistors are good choices



Design Parameter Suggestion

QN1 = MMBT5179TR-ND
QN2 = MMBT5179TR-ND
R1 = 11 kΩ
R2 = 5.6 kΩ
R3 = 330 Ω
R4 = 0 Ω (can be removed)
R5 = 33 kΩ (must be ±1%)
R6 = 6.2 kΩ (must be ±1%)
R7 = 51 kΩ
C1 = 1 nF
C2 = 1 nF
C3 = 1 nF

Figure 5. Q-Signal Boost Circuitry Suggestion

Simulation has been done with the circuit shownin Figure 6 at different corner conditions.

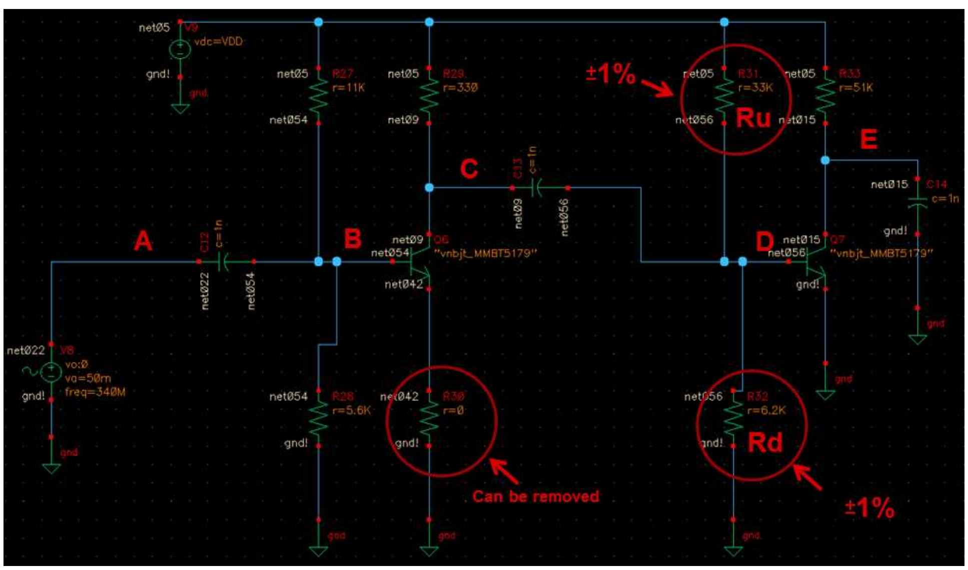


Figure 6. Q-Signal Boost Circuitry for Simulation

Figure 7 shows the waveform from a simulation with a clock input of 70-mV swing under typical temperature and Vcc conditions.

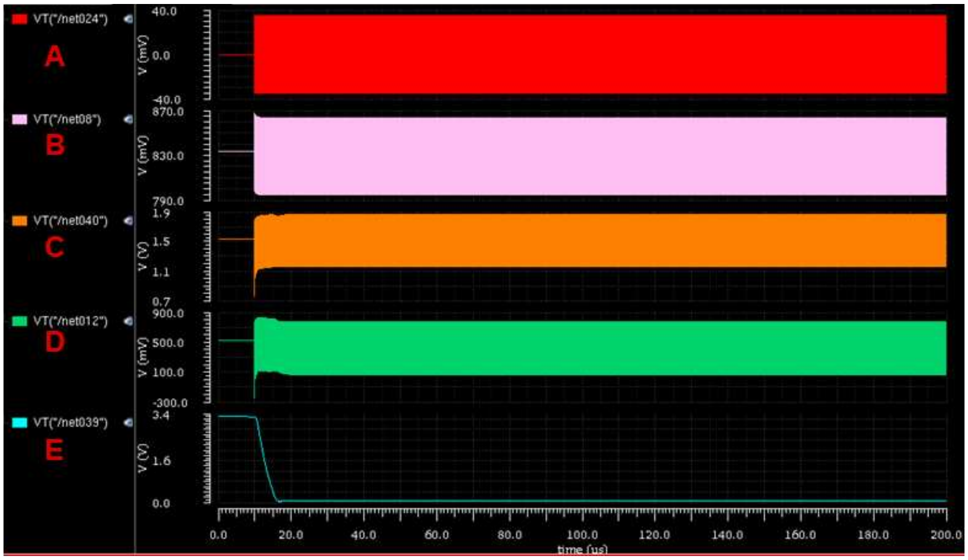


Figure 7. Typical Waveforms From Simulation

TI completed a simulation with corner cases and the results suggest that a well-designed circuit with pullup and pulldown resistors (R5 and R6) and Vcc with 1% tolerance will allow the MCU to detect signals with down to a 70-mV swing level under 0–70°C temperature conditions.

Table 3. Summary of Simulation Result for Corner Cases

				Worst for VOL	Typical			Worst for VOH	
70mV swing at A	Simulation Condition	Temp	0C	0C	0C	27C	70C	70C	70C
		VDD	3.3V-10%	3.3V-5%	3.3V-1%	3.3V	3.3V+1%	3.3V+5%	3.3V+10%
		Ru and Rd	Ru+1% Rd-1%	Ru+1% Rd-1%	Ru+1% Rd-1%	/	Ru-1% Rd+1%	Ru-1% Rd+1%	Ru-1% Rd+1%
	Output Level	VOH	2.77V	1.22V	94mV	49mV	38mV	38mV	35mV
		VOL	2.97V	3.135V	3.269V	3.298V	3.245V	3.287V	3.202V
				Worst for VOL	Typical			Worst for VOH	
100mV swing at A	Simulation Condition	Temp	0C	0C	0C	27C	70C	70C	70C
		VDD	3.3V-10%	3.3V-5%	3.3V-1%	3.3V	3.3V+1%	3.3V+5%	3.3V+10%
		Ru and Rd	Ru+1% Rd-1%	Ru+1% Rd-1%	Ru+1% Rd-1%	/	Ru-1% Rd+1%	Ru-1% Rd+1%	Ru-1% Rd+1%
	Output Level	VOH	1.29V	62mV	43mV	36mV	31mV	31mV	30mV
		VOL	2.97V	3.135V	3.269V	3.298V	3.245V	3.287V	3.202V
				Worst for VOL	Typical			Worst for VOH	
130mV swing at A	Simulation Condition	Temp	0C	0C	0C	27C	70C	70C	70C
		VDD	3.3V-10%	3.3V-5%	3.3V-1%	3.3V	3.3V+1%	3.3V+5%	3.3V+10%
		Ru and Rd	Ru+1% Rd-1%	Ru+1% Rd-1%	Ru+1% Rd-1%	/	Ru-1% Rd+1%	Ru-1% Rd+1%	Ru-1% Rd+1%
	Output Level	VOH	85mV	43mV	35mV	30mV	26mV	26mV	25mV
		VOL	2.97V	3.135V	3.269V	3.298V	3.245V	3.287V	3.202V

3 Conclusion

With a TMDS clock or signal-detection circuitry implemented, the HDMI source can determine TMDS receiver termination and transmit clock and signal when the user activates the source from its standby mode, and eventually HDMI sink can detect TMDS clock or signal running and wake up the system without any control.

Table 4. HDMI Sink can Wake-Up Without CEC

Device Power State No CEC Supported		Without TMDS Clock Detector		With TMDS Detector	
HDMI Sink	**HDMI Source**	**R_{Term}**	**Source Remote Control Causes Wake-Up**	**R_{Term}**	**Source Remote Control Causes Wake-Up**
Active	Active	Yes	-	Yes	-
Active	Standby	Yes	-	Yes	-
Standby	Active	No	No	Yes	Yes
Standby	Standby	No	No	Yes	Yes

Figure 8. Single Remote Controller for Both HDMI Sink and Source

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265