TEXAS INSTRUMENTS

Application Report

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Choosing an Optocoupler for the ADS1202 Operating in Mode 1

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ABSTRACT

The ADS1202 is a precision, 80dB dynamic range, delta-sigma ($\Delta\Sigma$) modulator operating from a single +5V supply. The differential inputs are ideal for direct connections to transducers or low-level signals. With the appropriate digital filter and modulator rate, the device can be used to achieve 15-bit analog-to-digital (A/D) conversion with no missing codes. This application report describes how to choose an appropriate optocoupler for isolated applications involving the ADS1202 in motor control current measurements.

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1 Introduction

In digital designs, when incoming data is read by a DSP or other host processor, it is important to know and match requirements for set up and delay times. The proper design requires knowledge of the set up time to the host as well as the delay time of the output data, relative to the clock signal edge. If the setup timing is not matched to the requirements specified by the DSP, the output data is misread. When a signal is transferred by an optocoupler, the designer must take special care of additional delays caused by pulse distortion and propagation skew. For these reasons, it is important to understand the specified timings of the ADS1202 and the optocoupler chosen for a particular application. This application report analyzes the effects of pulse width distortion parameters in the choice of an optocoupler. This analysis should be applied when two channels in one package (dual optocoupler) are used. For parallel data transmission, where two single channel optocouplers are used, the propagation delay skew parameter analysis should be applied. Unfortunately, not all manufactures publish this data; therefore, in such cases, previous analyses must be used.

2 The Optocoupler for the ADS1202

For a better understanding of the signals coming from the ADS1202 (the optocoupler input), and going to the host processor (the optocoupler output), please refer to Figure 1. The discussion that follows assumes that: MCLK and MDAT are signals coming from the ADS1202; $MCLK_{HL}$ represents the high-to-low transition of MCLK; $MCLK_{LH}$ represents the low-to-high transition of MCLK; and the same analogy can be applied to $MDAT_{HL}$ and $MDAT_{LH}$ transitions.

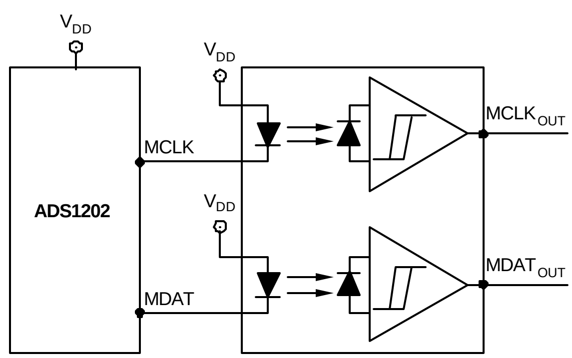

Figure 1. Reference Signals for the ADS1202 and the Optocoupler

$MCLK_{OUT}$ and $MDAT_{OUT}$ are output signals from the optocoupler. $MCLK_{HL}$OUT represents the high-to-low transition of $MCLK_{OUT}$. $MCLK_{LH}$OUT represents the low-to-high transition of $MCLK_{OUT}$. As with the optocoupler input signals, the same specification is applied to $MDAT_{HL}$ and $MDAT_{LH}$ transitions.

3 ADS1202 Timing Operating in Mode 1

In Mode 1, one input signal (M0) is high and the other (M1) is low. The internal 20MHz RC oscillator provides a clock signal to the delta-sigma modulator. This clock signal is divided by four, and sent out as MCLK, with a nominal 5MHz frequency. The output signal from the delta-sigma modulator DATA is also the MDAT signal coming from the ADS1202. The signal timings for mode 1 operation are presented in Figure 2. In this mode, the DSP or µC read data on every edge, rising and falling, of the output clock.

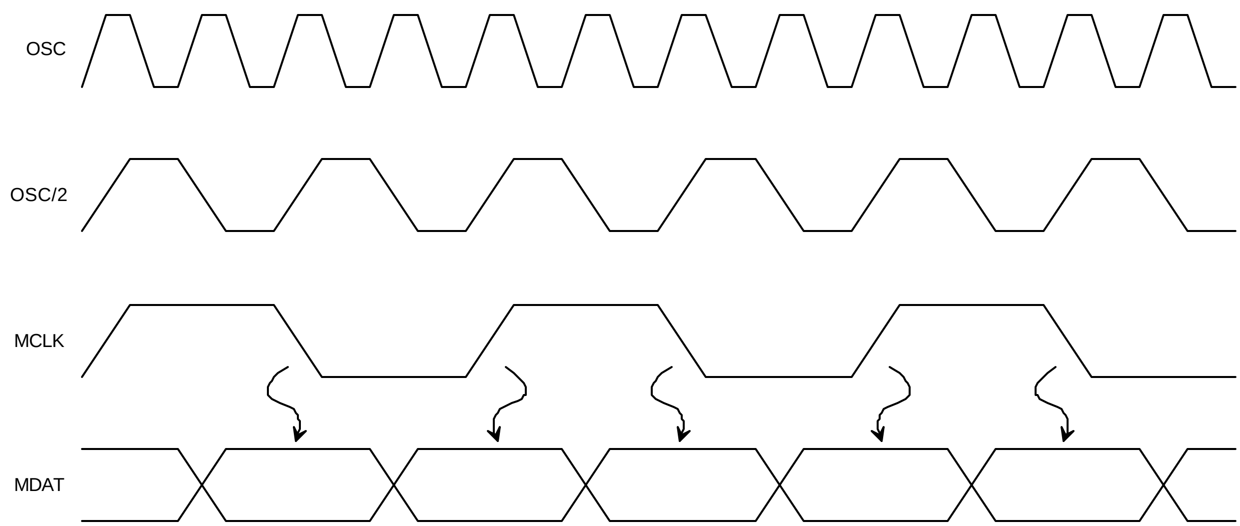

Figure 2. ADS1202 Waveform in Mode 1

3.1 Data Delay and Setup Time

It is important to know and understand the parameters affecting set up and delay times of the output data, relative to the clock signal edge. If the timing is not within the specifications of the DSP or other digital circuit, the output data is misread. When a signal is transferred through optocouplers, the designer must take special care of additional delays caused by the optocoupler. Understanding the specified timings of the ADS1202 and optocoupler are critical for an efficient design.

The MDAT signal changes on the falling edge of the OSC/2. The stability of the MCLK output, as well as the duty cycle, depends only on the jitter value of the internal oscillator. The ADS1202 oscillator jitter is less than 50ps.

See Figure 3 for the delay time (t_{D2}) after the rising edge of the clock signal, relative to the set up time (t_{S2}) of the output. See Table 1 for the ADS1202 values of t_{D2} and t_{S2} for various oscillator frequencies.

Table 1. The ADS1202 MDAT Setup and Delay Time—MCLK Rising

OSC	MCLK	t_{C2}	$t_{C2}/4$	t_{D2}			t_{S2}		
				Min	Typ	Max	Min	Typ	Max
(MHz)	(MHz)	(ns)	(ns)	(ns)	(ns)	(ns)	(ns)	(ns)	(ns)
16	4	250	62.5	60.5	61.5	62.5	62.5	63.5	64.5
20	5	200	50	48	49	50	50	51	52
24	6	167	41.8	39.7	40.7	41.7	41.7	42.7	43.7

Note: The setup and delay times listed are with respect to the rising edge of MCLK.

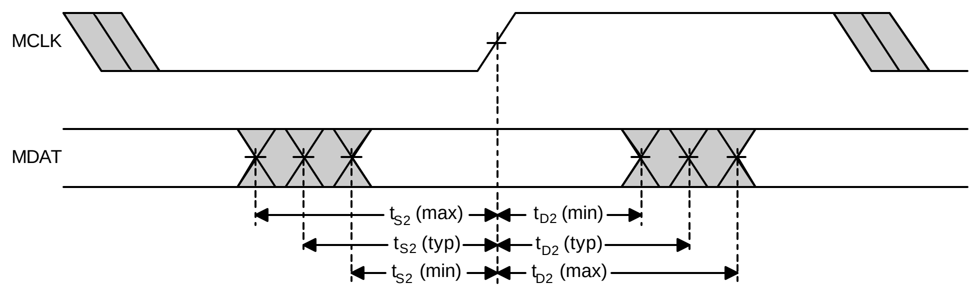

Figure 3. The ADS1202 MDAT Output Signal on the Rising Edge of MCLK

Figure 4 shows the delay time (t_{D3}) after the falling edge of the clock signal, relative to the set up time (t_{S3}) of the output. Table 2 shows values of t_{D2} and t_{S2} of the ADS1202 for various oscillator frequencies.

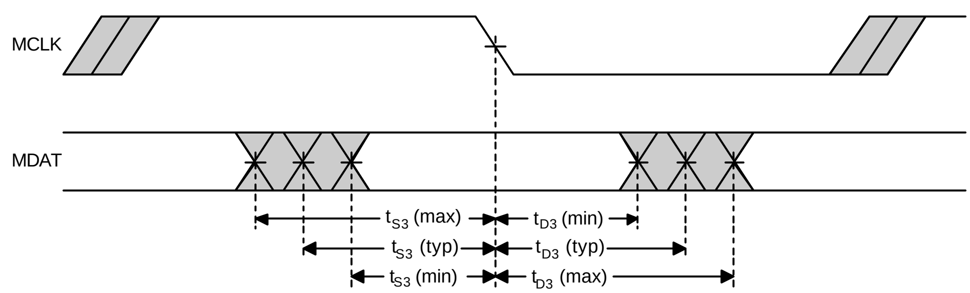

Figure 4. The ADS1202 MDAT Output Signal on the Falling Edge of MCLK

Table 2. The ADS1202 MDAT Setup and Delay Time—MCLK Falling

OSC	MCLK	t_{C2}	$t_{C2}/4$	t_{D3}			t_{S3}		
				Min	Typ	Max	Min	Typ	Max
(MHz)	(MHz)	(ns)	(ns)	(ns)	(ns)	(ns)	(ns)	(ns)	(ns)
16	4	250	62.5	60.5	61.5	62.5	62.5	63.5	64.5
20	5	200	50	48	49	50	50	51	52
24	6	167	41.8	39.7	40.7	41.7	41.7	42.7	43.7

Note: The setup and delay times listed are with respect to the falling edge of MCLK.

4 Choosing an Optocoupler Using the Pulse-Width Distortion Parameter

Under the same working conditions as those set up by the manufacturer, such as temperature and forward driving current, (refer to the ADS1202 data sheet, SBAS275, at www.ti.com) the optocoupler is specified with different values of t_{PLH} and t_{PHL}. This difference is normally expressed as an absolute value. When the ADS1202 is working in Mode 1, the MDAT output is sampled on both the rising and falling edge of MCLK. For the following analysis, assume that t_{PLH} is smaller than t_{PHL}. It is also possible to make a similar analysis assuming that t_{PLH} is greater than t_{PHL}. In either case, this does not change the optocoupler.

Appendix A and Appendix B explain in more detail the nature of pulse width distortion and how manufacturers specify this parameter. The specified pulse distortion is implemented on the output signal from the ADS1202 for future study. Combined parameters leads to the criterion that needs to be implemented in the system design.

Figure 5 shows waveforms for both the clock and the data lines being sent through the inverting optocouplers. Figure 5 illustrates data and clock signals at the inputs (MCLK and MDAT) and outputs ($MCLK_{OUT}$ and $MDAT_{OUT}$) of the optocouplers. The MDAT can change from low to high or from high to low on both the rising and falling edge of MCLK.

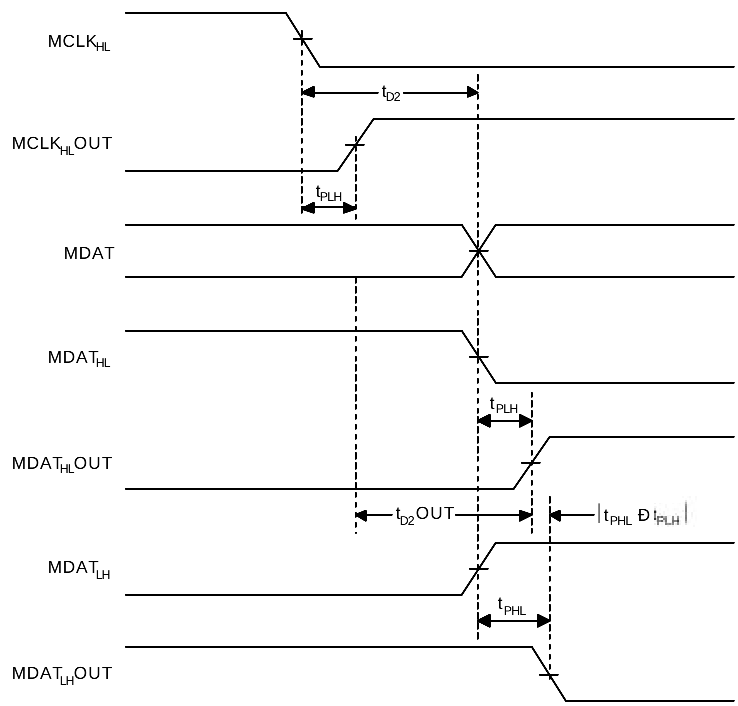

Figure 5. Delay Time on the Falling Edge of MCLK

The delay time of the output signal from an optocoupler based on the falling edge of MCLK can easily be calculated as shown in Equation 1, which shows the delay of the output signal $t_{D2}OUT$.

$$t_{D2} \le t_{D2}OUT \le t_{D2} + |t_{PHL} - t_{PLH}| \qquad \textit{Equation 1}$$

Figure 6 shows the delay time of the output signal from an optocoupler in the case of a rising edge of MCLK. It can easily be calculated as shown in Equation 2, which shows the delay of the output signal $t_{D3}OUT$.

$$t_{D3} - \left|t_{PHL} - t_{PLH}\right| \leq t_{D3}OUT \leq t_{D3} \qquad \text{Equation 2}$$

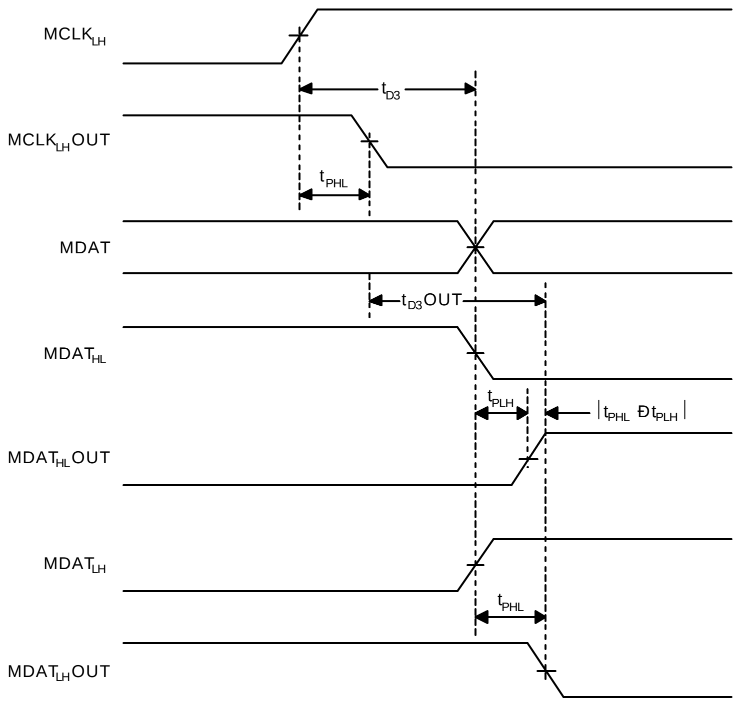

Figure 6. Delay Time on the Rising Edge of MCLK

From Equations 1 and 2, the first guideline in choosing an optocoupler can be obtained. In any case, the absolute difference in value between t_{PLH} and t_{PHL} must be smaller than the insured minimum ADS1202 delay time of t_{D2} and t_{D3}. This criteria is described in Equation 3.

$$\left|t_{PHL} - t_{PLH}\right| \leq \left(t_{D2} \wedge t_{D3}\right) \qquad \textit{Equation 3}$$

See Figure 7 for the setup time of the output signal in the case of a falling edge of MCLK. The setup of the output signal $t_{S2}OUT$ can easily be calculated, as shown in Equation 4.

$$t_{S2} - \left|t_{PHL} - t_{PLH}\right| \leq t_{S2}OUT \leq t_{S2} \qquad \textit{Equation 4}$$

See Figure 8 for the setup time of the output signal in the case of a rising edge of MCLK. It can easily be calculated as shown in Equation 5, which shows the setup of the output signal $t_{S3}OUT$.

$$t_{S3} \leq t_{S3}OUT \leq t_{S3} + \left|t_{PHL} - t_{PLH}\right| \qquad \textit{Equation 5}$$

From Equations 4 and 5, a second guideline in choosing an optocoupler can be obtained. In any case, the absolute difference in value between t_{PLH} and t_{PHL} must be smaller than the minimum ADS1202 setup time of t_{S2} and t_{S3}. This criterion is described in Equation 6.

$$\left|t_{PHL} - t_{PLH}\right| \leq \left(t_{S2} \wedge t_{S3}\right) \qquad \text{Equation 6}$$

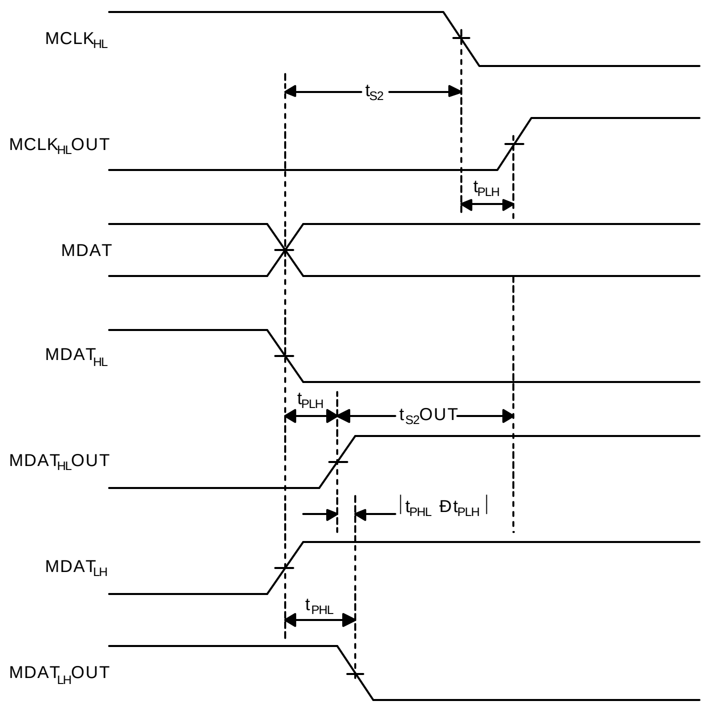

Figure 7. Setup Time on the Falling Edge of MCLK

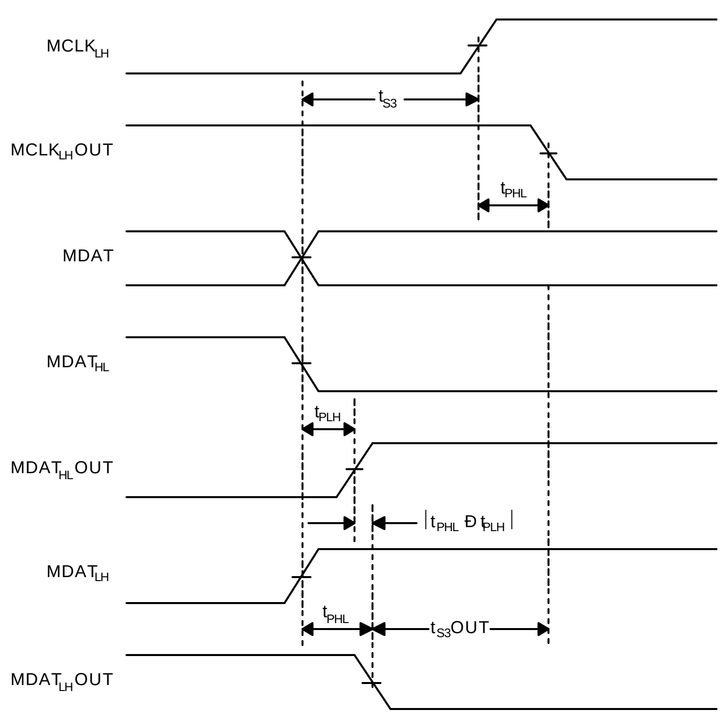

Figure 8. Setup Time on the Rising Edge of MCLK

5 Choosing an Optocoupler Using the Propagation Delay Skew Parameter

Propagation delay skew, t_{PSK}, is one of the most important parameters to be considered when parallel data streams are being sent through a group of optocouplers. Unfortunately, not all manufacturers specify this parameter, in which case the choice must be made using a pulse width distortion (PWD) specification. For the following analysis, assume that t_{PLH} is smaller than t_{PHL} and that the uncertainty of t_{PLH} is greater than the uncertainty of t_{PHL}. It is also possible to make a similar analysis assuming the opposite is true. In either case, this does not change the optocoupler requirements.

If the inputs of a group of optocouplers are switched either on or off at the same time, t_{PSK} is the difference between the shortest propagation delay, either t_{PLH} or t_{PHL}, and the longest propagation delay, either t_{PLH} or t_{PHL} (see Figure 15 with additional details in Appendix C).

See Figure 9 for the delay time of the output signal in the case of a falling edge of MCLK. It can be seen from Figure 9 that the only critical parameter in this case is to ensure that the $MCLK_{HL}OUT$ signal is set up before the $MDAT_{HL}OUT$ signal or before $MDAT_{LH}OUT$ starts to change. Equation 7 describes the process if the t_{PSK} parameter is used to cover uncertainties.

$$t_{PKS} \leq t_{D2} \qquad \textit{Equation 7}$$

See Figure 10 for the delay time of the output signal in the case of a rising edge of MCLK. Using the same specification, Equation 8 describes the limitation of delay time.

$$t_{PSK} \leq t_{D3} \qquad \textit{Equation 8}$$

From Equations 7 and 8, the first guideline in choosing an optocoupler using the propagation delay skew parameter can be obtained. In any case, t_{PSK} must be smaller than the insured minimum ADS1202 delay time of t_{D2} and t_{D3}. This criterion is described in Equation 9.

$$t_{PSK} \leq (t_{D2} \wedge t_{D3}) \qquad \text{Equation 9}$$

See Figure 11 for the setup time of the output signal in the case of a falling edge of MCLK. From Figure 11, it is obvious that the setup time must be greater than the propagation delay skew time of the chosen group of optocouplers, as shown in Equation 10.

$$t_{PSK} \leq t_{S2} \qquad \text{Equation 10}$$

See Figure 12 for the setup time of the output signal in the case of a rising edge of MCLK. It can easily be seen that in the worst-case condition (see Figure 11), the setup time must be greater than the propagation delay skew time, as shown in Equation 11.

$$t_{PSK} \leq t_{S3} \qquad \text{Equation 11}$$

From Equations 9 and 10, a second guideline in choosing an optocoupler using the pulse delay skew parameter can be obtained. In any case, as for the delay time, t_{PSK} must be smaller than the insured minimum ADS1202 setup time of t_{S2} and t_{S3}. This criterion is described in Equation 12.

$$t_{PSK} \leq (t_{S2} \wedge t_{S3}) \qquad \text{Equation 12}$$

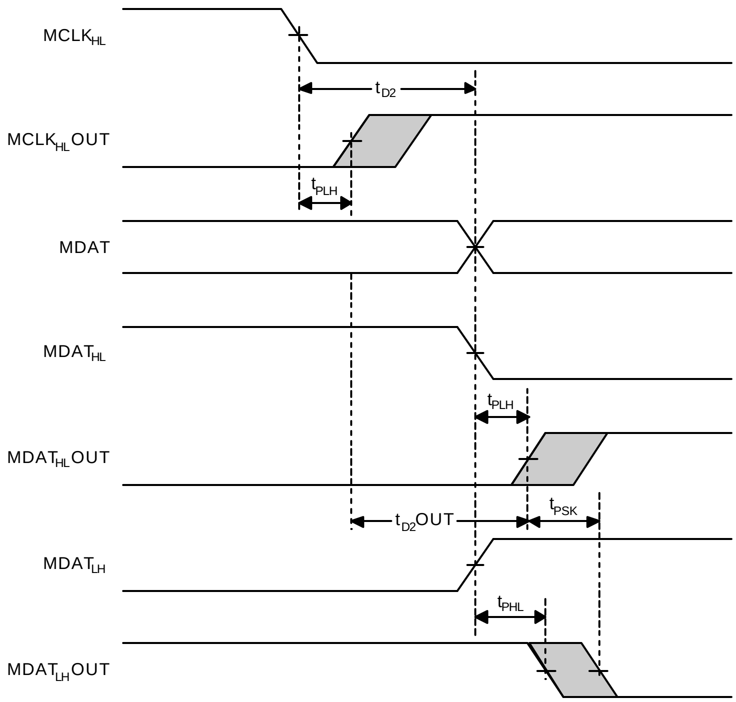

Figure 9. Delay Time on the Falling Edge of MCLK

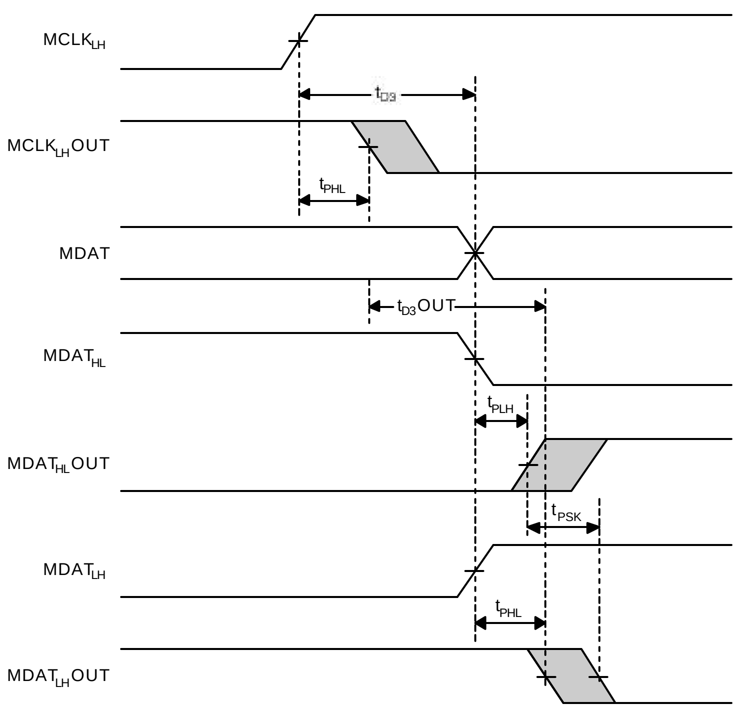

Figure 10. Delay Time on the Rising Edge of MCLK

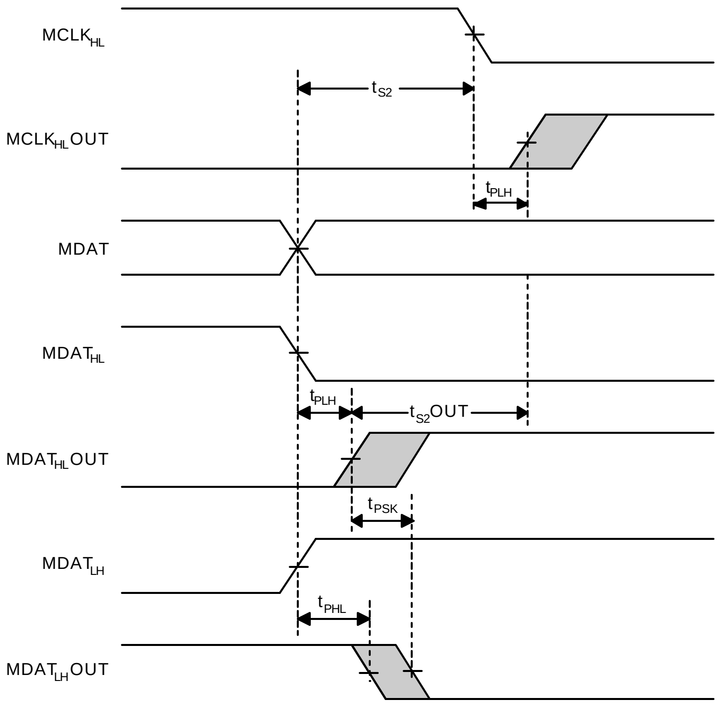

Figure 11. Setup Time on the Falling Edge of MCLK

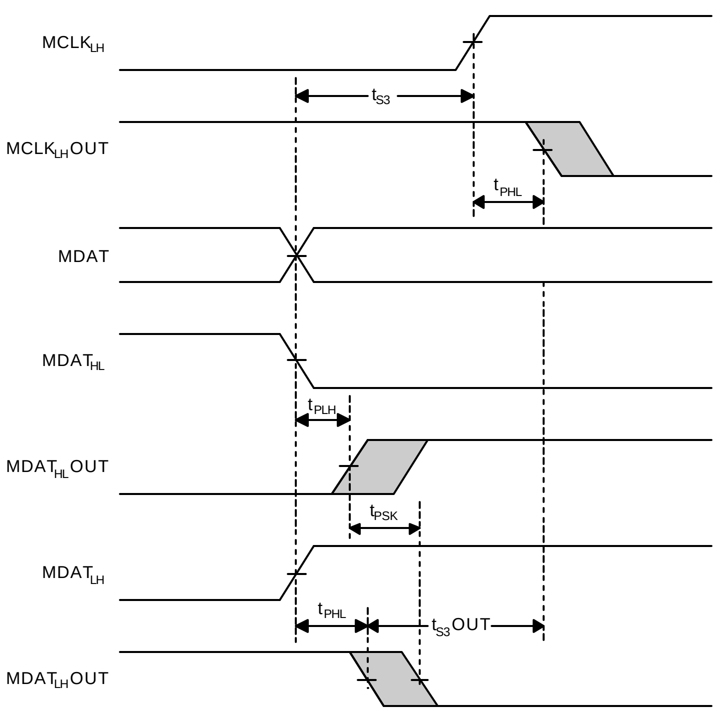

Figure 12. Setup Time on the Rising Edge of MCLK

6 Conclusion

The ADS1202 internal oscillator can range from 16MHz to 24MHz. In the worst case, for the maximum ensured oscillator frequency of 24MHz, or output clock MCLK of 6MHz, the minimum delay and set up times are:

$$t_{D2} = 39.7ns$$
$$t_{S2} = 41.7ns$$
$$t_{D3} = 39.7ns$$
$$t_{S3} = 41.7ns$$

Appendix D presents a table with a list of several optocoupler manufacturers. The propagation delay times of these representative optocouplers are presented in Table 3. The pulse-width distortion is presented in Table 4 and the pulse skew time in Table 5. Referring to Equations 3, 6, 9, and 12, and knowing the specified parameters of the ADS1202, it is easy to make a selection of applicable optocouplers for a specific application.

As a conclusion of the previous analysis, the optocoupler choice (when considering the pulse-width distortion parameter) must satisfy the following criteria:

$$\left|t_{PHL} - t_{PLH}\right| \leq 39.7ns$$

Furthermore, the optocoupler choice (when considering the propagation delay skew parameter) must satisfy the following criteria:

$$t_{PSK} \leq 39.7ns$$

Appendix A: Optocoupler Propagation Delay Characteristics

One of the primary specifications that optocoupler manufacturers specify is propagation delay time. Propagation delay defines how quickly a logic signal propagates through the optical system. The propagation delay from low to high (t_{PLH}) is the amount of time required for an input signal to propagate to the output, causing the output to change from low to high. Similarly, the propagation delay from high to low (t_{PHL}) is the amount of time required for the input signal to propagate to the output, causing the output to change from high to low. It is commonly specified for the input signal or forward current of the internal light emitting diode (LED), as a corresponding delay time with regards to the output voltage. The propagation delay time of the output signal (V_O), as a function of input forward current (I_F), is presented in Figure 13.

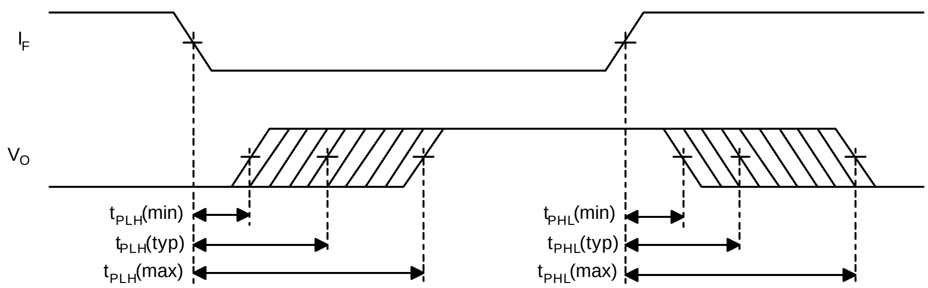

Figure 13. Propagation Delay Time of Low and High Output Levels

The specified minimum, typical, and maximum delay times are dependent on different factors. These times typically change as a function of temperature, withstand voltage, or input current. Table 3 contains the typical propagation delay times for several optocouplers.

Table 3. Propagation Delay Time for Different Optocouplers

	Units	HCPL-2631 Various	HCPL-2400 Agilent	IL711 NVE	ISO150 TI
t_{PLH} (min)	ns	20	15	—	20
t_{PLH} (typ)	ns	48	30	10	27
t_{PLH} (max)	ns	75	60	15	40
t_{PHL} (min)	ns	25	15	—	20
t_{PHL} (typ)	ns	50	33	10	27
t_{PHL} (max)	ns	75	60	15	40

The t_{PHL} propagation delay is typically measured from the 50% level on the rising edge of the input current pulse to the 1.5V level on the falling edge of the output voltage pulse. The t_{PLH} propagation delay is typically measured from the 50% level on the falling edge of the input current pulse to the 1.5V level on the rising edge of the output voltage pulse.

Appendix B: Optocoupler Pulse-Width Distortion Characteristics

Another common parameter that optocoupler manufacturers specify is pulse-width distortion (PWD). PWD results when t_{PLH} and t_{PHL} differ in value for the same working conditions—such as temperature and forward driving current. PWD is defined as the absolute difference between t_{PLH} and t_{PHL}. It often determines the maximum data rate capability of a transmission system. PWD can be expressed in percent by dividing the PWD (in ns) by the minimum pulse width (in ns) being transmitted. Typically, PWD on the order of 20 to 30% of the minimum pulse width is tolerable; the exact figure depends on the particular application. The pulse-width distortion of the output signal (V_O), as a function of input forward current (I_F), is shown in Figure 14. Table 4 contains the typical pulse-width distortion for several optocouplers.

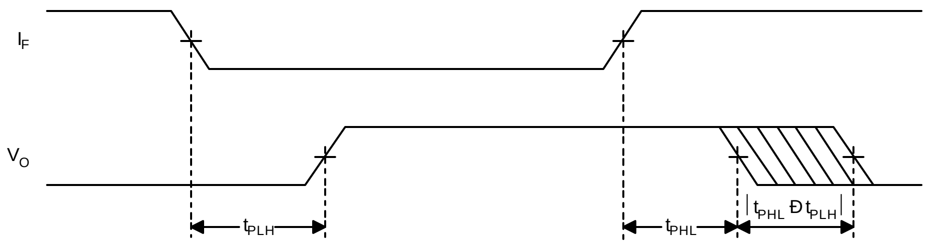

Figure 14. Pulse-Width Distortion of the Output

Table 4. Pulse-Width Distortion for Different Optocouplers

	Units	**HCPL-2631** **Various**	**HCPL-2400** **Agilent**	**IL711** **NVE**	**ISO150** **TI**
t_{PWD} (min)	ns	—	—	—	—
t_{PWD} (typ)	ns	3.5	2	2	1.5
t_{PWD} (max)	ns	35	15	3	6

Appendix C: Optocoupler Propagation Delay Skew Characteristics

Propagation delay skew (t_{PSK}), is an important parameter to consider in applications where synchronization of signals on parallel data lines is a concern. For applications with the ADS1202, t_{PSK} is one of the most important parameters to be considered. If parallel data streams are being sent through a group of optocouplers, differences in propagation delay will cause skewing. If this difference in propagation delay is large enough, it will limit the maximum rate at which parallel data can be sent through the optocouplers.

Propagation delay skew is defined as the difference between the minimum and maximum propagation delays, either t_{PLH} or t_{PHL}, for any given group of optocouplers that are operating under the same conditions (i.e., the same drive current, supply voltage, output load, and operating temperature).

If the inputs of a group of optocouplers are switched either on or off at the same time, t_{PSK} is the difference between the shortest propagation delay, either t_{PLH} or t_{PHL}, and the longest propagation delay, either t_{PLH} or t_{PHL}, as shown in Figure 15. Table 5 contains the typical propagation delay skew for several optocouplers.

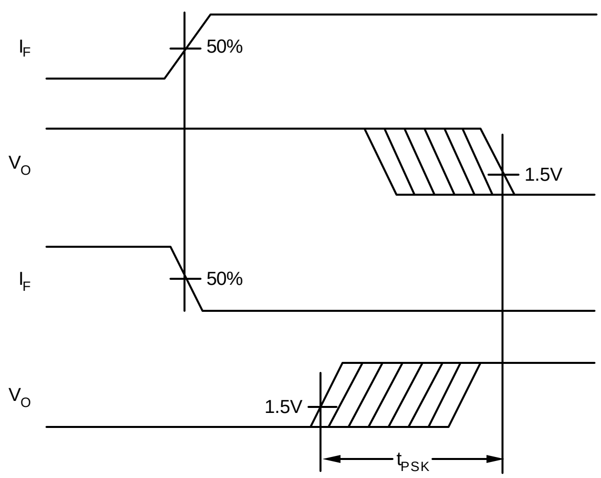

Figure 15. Illustration of the Propagation Delay Skew—t_{PSK}

Table 5. Propagation Delay Skew for Different Optocouplers

	Units	HCPL-2631 Various	HCPL-2400 Agilent	IL711 NVE	ISO150 TI
t_{PSK} (min)	ns	—	—	—	—
t_{PSK} (typ)	ns	—	—	4	0.5
t_{PSK} (max)	ns	40	35	6	2

Appendix D: Optocoupler Manufacturers

Table 6. Manufacturer Web Sites

Manufacturer	Web Site
Couplers	
Agilent (formerly HP)	http://www.semiconductor.agilent.com/cgi-bin/morpheus/home/home.jsp?pSection=Optocoupler
NVE Corp.	http://www.nve.com/
Fairchild Semiconductor	http://www.fairchildsemi.com/
NEC Electronics	http://www.necel.com/
Sharp Microelectronics	http://www.sharpsma.com/sma/products/Optoelectronics.htm
Toshiba	http://www.toshiba.com/taec/cgi-bin/display.cgi?table=Family&FamilyID=19
Vishay	http://www.vishay.com/products/optoelectronics/OPC.html
Sensors and Diodes	
OSRAM Opto Semiconductors (formerly Infineon, Siemens)	http://www.osram.convergy.de/scripts/product_class.asp?CLSOID=10001
Optek	http://www.optekinc.com/
Very High Isolation Devices	
IsoCom Components	http://www.isocom.com/
Bedford Opto Technology	http://www.bot.co.uk/

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