Optocoupler Common Mode Transient Immunity (CMTI) - Theory and Practical Solutions

INTRODUCTION

This application note discusses the common mode transient immunity (CMTI) properties of optocouplers. It covers phototransistor output and optically coupled logic gates.
The common mode transient immunity, (CMTI), common mode transient rejection (CMTR), or common mode rejection (CMR), is a measure of optocoupler's output amplifier to reject fast transient noise signals that are present between the input (LED) and the output side of the optocoupler.
To characterize the CMTI behavior of an optocoupler it is necessary to describe it with two values:

- V_{CM} - common mode voltage ($V_{CM} = \Delta V_{CM}$)
- dV/dt - rate of rise or fall of the common mode voltage ($dV/dt = \Delta V_{CM}/t_r$ or $dV/dt = \Delta V_{CM}/t_f$)

Figure 1 shows how these two values are defined.
Only when both values are specified, the CMTI can be evaluated properly. The ability of the optocoupler to withstand a given common mode transient is called common mode transient immunity at logic low level or logic high level, the abbreviation is CM_L or CM_H. The optocoupler fails if its output 'high' voltage drops below 2.0 V or its output 'low' voltage rises above 0.8 V, in the presence of the common mode transient noise signal.

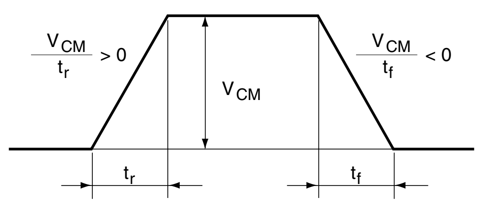

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Fig. 1 - Definition of the Common Mode Signal

The effects of common mode transients in an electronic circuit are numerous, starting with distortions in the output voltage, continuing to a complete false turn on or off of the optocoupler. Figure 2 shows an example.

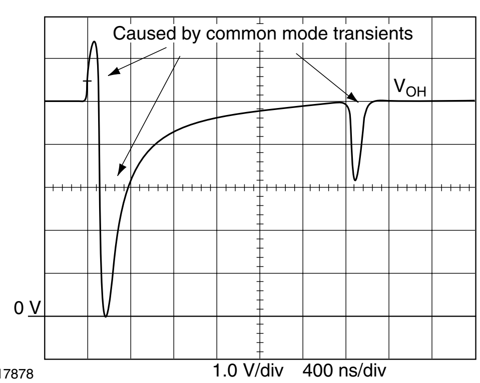

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Fig. 2 - Typical Output Signal Distortion of a Optocoupler when Excessive Common Mode Voltage is Applied
(SFH6136 with V_{CM} = 2.0 kV, dV/dt = 20 kV/µs, I_F = 0 mA)

It is hard to determine, if a circuit is affected by common mode transients, and if it is necessary to take actions to avoid any possible influence. Below are listed some applications, where common mode problems might occur:

- Driving IGBTs
- Switching loads especially high voltage or high current loads very fast
- Driving motors
- Wires or tracks near fast switched high power devices
- Floating power supplies
- High speed applications
- High electromagnetic interference (EMI) environment

If it is necessary to avoid any common mode transient problem, the circuit designer has several possibilities. This starts with proper circuit design and ends with choosing the right devices.

THEORY OF COMMON MODE EFFECTS

The following section covers transistor optocouplers, and is mainly intended for the circuit designer who wants to understand the causes and their effects when common mode transients occur.
The circuit, presented in figure 3, shows one 'basic' optocoupler application circuit.

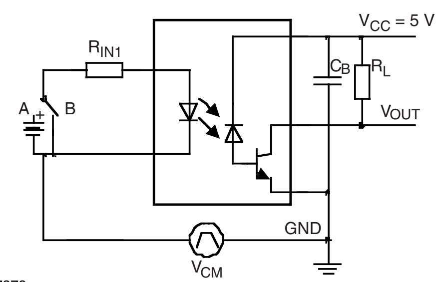

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Fig. 3 - Typical Setup to Investigate Common Mode Transients

To understand the effects of common mode transients, it is necessary to have a detailed look on the optocoupler's internal body with special focus on parasitic capacitances.

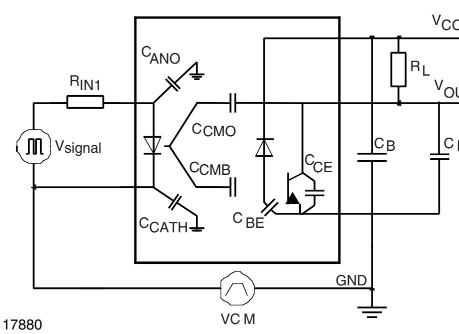

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Fig. 4 - Schematic of the Internal Electrical Elements of an Optocoupler

- The capacitances C_{ANO} and C_{CATH} represent the parasitic capacitances to ground or virtual ground from either anode or cathode.
- The capacitance C_{CMB} represents the coupling path into the base/photodiode of the detector and C_{CMO} represents the effective capacitance for the direct coupling path to the output or collector.
- C_L represent the load capacitance
- C_{CE} and C_{BE} are the capacitances of the output transistor
- C_{PD}, the capacitance of the photodiode, is added to $C_{BE,}$ as $C_{PD} \| C_{BE}$

The problems, which might occur during common mode transients, have three different root causes:

- Coupling to the collector via C_{CMO} (see section 2.1)
- Coupling into the base or photodiode via C_{CMB} (see section 2.2)
- An unintentional turn off or on of the LED during transients, caused by transient current through the parasitic capacitances C_{ANO} and C_{CATH} (see section 2.3)

As different as the root causes are, their effect on the output signal might be very similar and hard to differentiate.

The following two figures (figures 5 and 6) show how the output signal might look like, if excessive common mode voltage is applied. The test setup is according to the data book.

In figure 5 the SFH6136 represents a normal transistor optocoupler. In contrast, in figure 6 the SFH6711, an I_C coupler, has an active totem pole (logic level) output.

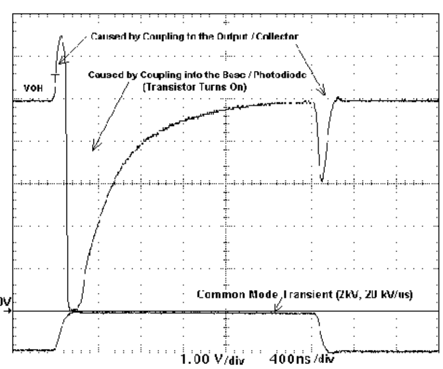

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Fig. 5 - Output Signal Distortion of an Optocoupler in the Presence of Excessive Common Mode Voltage (SFH6136 at I_F = 0 mA, V_{OUT} = 'high' Level, Setup According to Data Book)

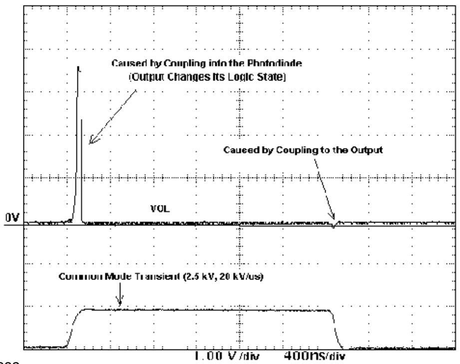

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Fig. 6 - Output Signal Distortion of an Optocoupler in the Presence of Excessive Common Mode Voltage (SFH6711 at I_F = 0 mA, V_{OUT} = 'low' Level, Setup According to Data Book)

The following sections describe various forms of CMTI and its impact on the couplers behavior more detailed.

Figure 7 presents the basic schematic for direct coupling to the collector via C_{CMO}.

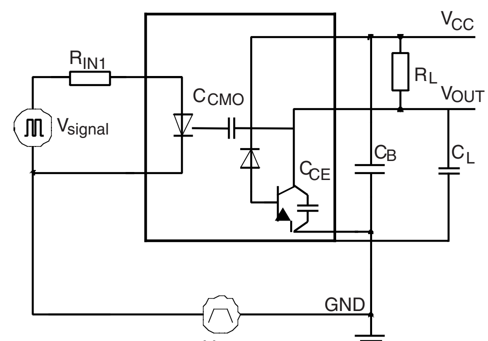

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Fig. 7 - Principle Schematic for Direct Coupling to the Output or Collector

In general there are two different (logic) states, which are analyzed below:

- Output at low state = LED on
- Output at high state = LED off

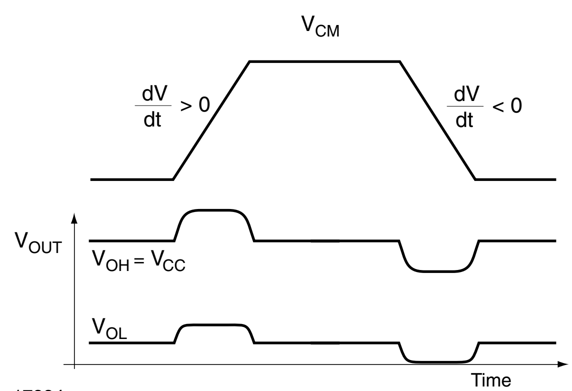

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Fig. 8 - Common Mode Pulse and the Distorted Output Signal

2.1.1 Output at High State, LED Off

For basic analysis the schematic in figure 7 can be reduced to a capacitive voltage divider, made out of C_{CMO} and C_L || C_{CE} During transients, V_{OUT} can be explained as:

$$V_{OUTx} = V_{OH} + \Delta V_{CM} \cdot \frac{C_{CMO}}{C_{CMO} + C_{CE} + C_L} \quad (1)$$

This equation leads to a minimum required common mode voltage to bring the output voltage V_{OUT} below a certain critical value.

$$\Delta V_{CMmin} > |V_{OUTx} - V_{OH}| \cdot \left(1 + \frac{C_{CE} + C_L}{C_{CMO}}\right) \quad (2)$$

Equation (1) shows that it is necessary to have a minimum negative common mode voltage change applied to bring the output below a certain voltage level (most definitions work with V_{OH} = 2.0 V, because of TTL logic compatibility).

The second point, which has to be taken into account is that the common mode signal has a minimum rate of voltage change that forces a current to flow through the common mode coupling capacitors and charge the transistor's collector-emitter and load capacitance. Equation (3) specifies the minimum rate (dV/dt) of the common mode voltage, based on the transistor collector current and common mode coupling capacitance.

$$\left|\frac{dV_{CM}}{dt}\right| > \frac{|\Delta i_C|}{C_{CMO}} \quad (3)$$

with

$$\Delta i_{Cx} = \frac{V_{OUTx} - V_{OH}}{R_L // r_{CE}} + (C_L + C_{CE}) \cdot \frac{d(V_{OUTx} - V_{OH})}{dt} \quad (4)$$

This shows that also a minimum dV_{CM}/dt is required to bring the output below a certain voltage.

In general the equations indicate that two requirements must be fulfilled by a common mode transient to cause the output voltage to drop below a certain voltage level:

- A minimum $|V_{CM}|$ (equation (2)) and
- A minimum $|dV_{CM}/dt|$ rate (equations (3) and (4)).

Whereby the falling edge of the common mode transient (negative dV/dt) is now the critical one.

2.1.2 Output at Low State, LED On

In the state, where the LED is on, the above considerations are also valid (equations (1) to (4)). However, as figure 8 indicates, the critical point is now the rising edge of the transient. Equation (4) shows that a low r_{CE} (transistor highly saturated) makes this case much more robust to any transients, compared to the LED off state.

2.1.3 Conclusion

As the above equations prove, the CM_H state is more critical to transients than the CM_L state (assuming to operate the transistor in saturated mode).

In summary, distortions in the output signal, caused by direct coupling to the transistors collector output, cause trouble if:

- ΔV_{CM} is higher than a minimum V_{CM}.
- The rate of rise/fall of the transient is higher than a minimum dV/dt.

Equation (4) also indicates that a low R_L improves the CMTI behavior of the circuit.

2.2 Coupling into the Base via CCMB

Figure 9 presents the general schematic which is useful in the discussion of coupling into the photodiode resp. base of the phototransistor.

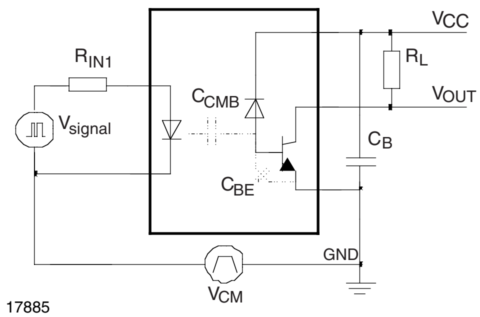

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Fig. 9 - Principle Schematic for Coupling into the Base or Photodiode

In general there are two different (logic) states, which are presented below:

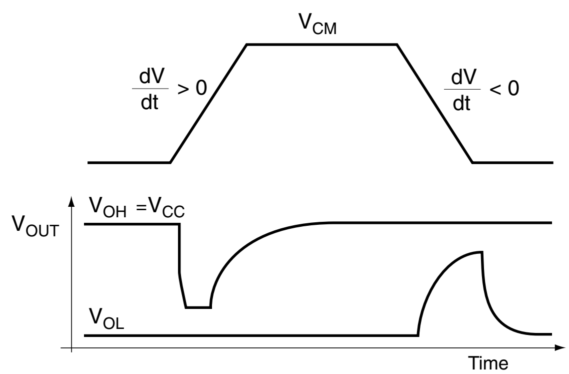

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Fig. 10 - Common Mode Signal an the Distorted Output Signal

2.2.1 Output at High State, LED Off

For basic analysis the schematic in figure 9 can be reduced to a capacitive voltage divider between C_{CMB} and C_{BE} (C_{BE} also includes the capacitance of the photodiode, C_{PD}) of the transistor. This leads to:

$$V_{BE} = V_{BEO} + \Delta V_{CM} \cdot \frac{C_{CMB}}{C_{CMB} + C_{BE}} \quad (5)$$

Therefore it is a minimum ΔV_{CM} required to bring the base-emitter voltage of the output-transistor up to the required turn-on voltage of around 0.6 V

$$\Delta V_{CMmin} > |V_{BE} - V_{BEO}| \text{ Þ } \left(1 + \frac{C_{BE}}{C_{CMB}}\right) \quad (6)$$

The above equations indicate that it is necessary to have a minimum positive common mode voltage change applied to turn on the output transistor.

It must also be considered that a base current (= I_{CE}/h_{FE}) is needed to force a high enough collector current I_C to cause a sufficient voltage drop across R_L. Equation (8) gives a good idea which minimum current is required:

$$\left|\frac{dV_{CM}}{dt}\right| > \frac{|\Delta i_B|}{C_{CMB}} \qquad (7)$$

$$\Delta i_B \approx \frac{V_{OH} - V_{OUT}}{R_L \cdot h_{FE}} \qquad (8)$$

To summarize it up, two requirements must be fulfilled by a common mode transient to cause the output voltage to drop below a certain voltage level:
a minimum $|\Delta V_{CM}|$ (equation (6)), and
a minimum $|dV_{CM}/dt|$ rate (equations (7) and (8))
Whereby the critical edge is the rising edge of the common mode transient (positive dV/dt).

2.2.2 Output at Low State, LED On

In the LED on state the above considerations are also valid (equations (5) to (8)). However, as figure 10 indicates, the critical point is now the falling edge of the transient. It can also be noticed that a fully saturated transistor improves the CMTI and makes the circuit much more robust to any transients.

2.2.3 Conclusion

Concerning coupling into the base or photodiode of the transistor, mostly the CM_H state is more critical to transients than the CM_L state (assuming to operate the transistor in saturation mode - linear mode operation is very sensitive). To summarize it up, distortions in the output signal, which are caused by direct coupling into the base or photodiode of the detector, cause trouble only if:

- The transient voltage change is higher than a minimum $|\Delta V_{CM}|$
- The rate of rise or fall of the transient is higher than the minimum $|dV_{CM}/dt|$

The above equation (8) also indicates that a low R_L improves the CMTI behavior of the circuit.

A significant improvement in reducing C_{CMB} is reached, if the base is not connected internally - this reduces C_{CMB} dramatically and coupling into the base can be reduced by magnitudes.

2.3 Unintentional Turn Off or On of the LED during Transients

Turning the LED on or off during transients is a major concern for all high speed, high CMTI and low I_F rated devices.

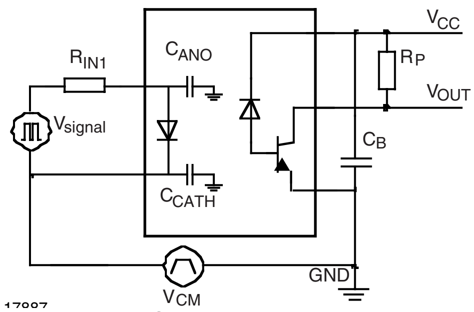

Fig. 11 - Principle Schematic for an Unintentional Turn Off or On of the LED during a Common Mode

In general there are two different (logic) states, which are analyzed below:

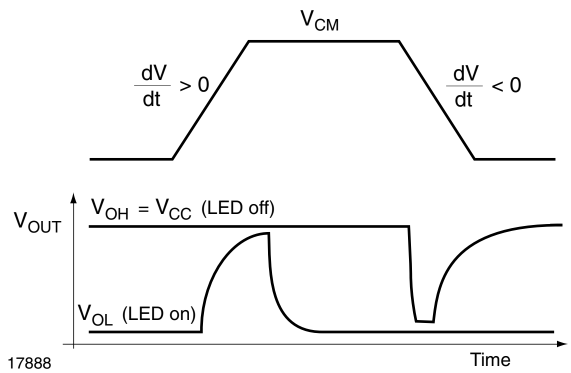

Fig. 12 - Common Mode Signal and the Distorted Output Signal

2.3.1 Output at High State, LED Off

During the rising edge of the common mode transient the capacitances C_{ANO} and C_{CATH} get charged up to V_{CM} (refer to figure 13).

In the first moment, when the transient pulse disappears, the capacitance C_{CATH} gets discharged directly. This discharging current is

$$I_{ANO} = C_{ATH} \bullet dV \S dt \text{ (negative dV/dt)} \qquad (9)$$

On the anode side, C_{ANO} has to be discharged via $R_{IN1}||LED$ with

$$I_{ANO} \approx C_{ANO} \bullet dV \S dt \text{ (negative dV/dt)} \qquad (10)$$

This means that the discharging current causes a voltage drop across $R_{IN1}||LED$, which is able to turn the LED on, and leads the detector to a reaction. Even if this happens just for a moment, it can cause a complete turn on of the detector in fast optocouplers. Especially low current types, like the 5.0 MBit/s device, are very sensitive to this effect (I_{Fon} threshold is typ. only 0.5 mA).

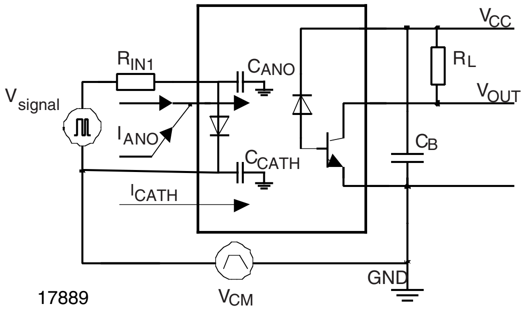

Fig. 13 - Principal Current Flow

2.3.2 Output at Low State, LED On

At the case, where the LED is on, the above considerations are also valid (equations (9) and (10)). However, as figure 12 indicates, the critical point is now the rising edge of the transient.

2.3.3 Conclusion

Although the behavior of the output signal appears like a 'optocoupler CMTI' problem, it is rather a circuitry problem than a property of the optocoupler itself.
To summarize it, two things are necessary to cause common mode transient trouble due to unintentional turn on or off of the LED:

- a high dV/dt rate, and
- an unbalanced LED input circuit together with high

parasitic input capacitances

- A high dV/dt rate, and
- An unbalanced LED input circuit together with high parasitic input capacitances

As it can be seen easily in figure 14, where $R_{IN1} = R_{IN2}$, the problem almost disappears (assuming $C_{ANO} = C_{CATH}$).
To ensure that the LED stays on, even during excessive common mode transients, a high LED forward current brings additional safety.

Another solution is to minimize C_{ANO} and C_{CATH}. In the worst case, a shielding of the anode/cathode might be necessary; the shielding potential can then be V_{CM} with respect to input ground. Connecting the unused input pins to input ground is a first step into this direction. But keep in mind that this action rises also C_{CMO} and might increase direct coupling to the output.

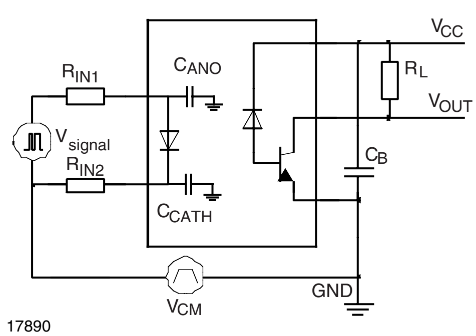

Fig. 14 - Balanced Input Circuit for Very High CMTI

2.4 Summary

Table 1 presents a short overview on the different coupling paths and the critical transient edge.

TABLE 1

	I_F ON	I_F OFF
C_{CMO}	if V_{OUT} = low: ↑	if V_{OUT} = high: ↓
	if V_{OUT} = high: ↓	if V_{OUT} = low: ↑
C_{CMB}	Standard Transistoroptocoupler: ↓	Standard Transistoroptocoupler: ↑
	SFH67XX - series ∗: ↑ and ↓	SFH67XX - series ∗: ↑ and ↓
C_{ANO} and C_{CATH}	↑ and ↓ (depends on input cicuit)	↑ and ↓ (depends on input cicuit)

Overview on the different coupling ways and the influence of the edge of the common mode transient.

Comments:

↑ symbolizes that the rising edge is the critical one sitive dV/dt)

↓ symbolizes that the falling edge is the critical one (negative dV/dt)

∗ this is caused by the internal input logic of the detector I_C

3. TECHNIQUES TO IMPROVE THE CMTI BEHAVIOR OF AN OPTOCOUPLER

According to the above mentioned equations, the internal coupling capacitances must be minimized. From basic point of view it is only necessary to reduce the single coupling capacitances.

- C_{CMO}: The C_{CMO} value is mainly determined by the internal construction of the optocoupler. Unfortunately there is not much room for improvement to reduce this value.
- C_{CMB}: There are two steps, which reduce the C_{CMB} significantly:
  - Using a transistor coupler where the base is not connected internally. This lowers the effective C_{CMB} by magnitudes and improves so the CMTI behavior. So, whenever CMTI could be an issue, and the base contact is not required, the first choice should be an optocoupler without external base contact. Besides higher CMTI, the missing base contact also gives the advantage of a lower leakage current.
  - If using a transistor coupler without internal base connection is not enough, it is necessary to use additional techniques to reduce the C_{CMB} value. This results in using a shielded device:
    In general the detector die is covered with grounded aluminum, except the photosensitive area. This metal shielding prevents any electrical influence into the detector electronics (even if it is just a simple phototransistor). One step further is to cover also the photosensitive area with an electrical conductive, but optical transparent material. A material typically used for this purpose is indium tin oxide (ITO) and reduces the effective C_{CMB}.

- C_{ANO}/C_{CATH}: This parasitic values are mainly determined by the internal construction of the optocoupler, the designed input circuitry and the board layout. A proper board layout and input circuit design are therefore necessary, especially for all high speed, high CMTI and low I_F rated types. One action might be to minimize C_{ANO} and C_{CATH} by connecting the input pins, which are not used to input ground. On the other hand, this action increases the effective C_{CMO}.

3.1 Indium Tin Oxide (ITO) - The Faraday Shield

The use of the ITO as a faraday shield on top of the detector die improves the CMTI behavior of optocouplers significantly. The physical property of this material makes it transparent to light, but electrically conductive, so that the transient current, which might turn the detector on or off is grounded. This decreases the effective C_{CMB} roughly by a factor of 10, and improves therefore the CMTI significantly.

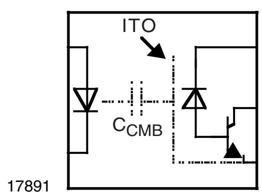

Fig. 15 - Optocoupler with ITO as a Faraday Shield, Principal Schematic

The table 2 lists some devices which make use of this technique.

3.2 Transparent Ion Shield (TRIOS) - Field Effect Stable Optocouplers

The TRIOS shielding makes the optocoupler stable against field effects, but has no influence on fast transients. The advantage of the TRIOS works when static electrical fields are applied to the optocoupler.
The TRIOS helps in high electrical fields to prevent excessive dark or leakage current or current gain drops and thus maintains the performance of the optocoupler in these harsh environments. All Vishay technologies standard optocouplers feature this transparent ion shield.

TABLE 2

DEVICE NUMBER	PACKAGE	SPEED	MINIMUM dV/dt	MINIMUM V_{CM}
SFH6345	DIP8	1.0 MBit/s	15 kV/µs	1500 V
SFH6343	SO8	1.0 MBit/s	15 kV/µs	1500 V
SFH6711/ 11/12/19	DIP8	5.0 MBit/s	2.5 kV/µs	400 V
SFH6721	SO8	5.0 MBit/s	2.5 kV/µs	400 V
SFH6732	DIP8 - dual channel	5.0 MBit/s	2.5 kV/µs	400 V

List of high speed and very high common mode transient immunity optocouplers which use ITO.

4. CHARACTERISTICS AND DESIGN GUIDELINES

The following Sections present guidelines and information on the various types of optocouplers, but without claiming to be complete and valid for every device, since every product has its own properties which influence CMTI in a different and hardly predictable way.

All the diagrams presented in the following sections refer to the following CMTI definition:

- V_{CC} = 5.0 V
- V_{OH}: V_O > 2.0 V
- V_{OL}: V_O < 0.8 V
- Setup: Detector in switched transistor mode with pull up resistor R_L - according to figure 3.

4.1 Standard Optocouplers without Base Contact

In general these optocouplers are very robust to common mode transients, due to the fact, that the base is not connected. Hence, the common mode transient immunity is mainly determined by direct coupling to the output via C_{CMO}. The duration of the output signal distortion matches with the transient change (rising or falling edge). Refer to figure 17. The following considerations only apply to systems which can react on distorted signals which are in the range of a few hundred nanoseconds and less. The off state (CM_H) is in most applications the critical one and limits so the overall performance. Figure 16 shows the typical dV/dt vs. V_{CM} curve for two different pull up resistor values.

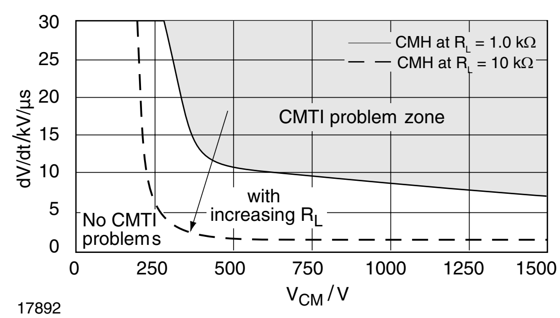

Fig. 16 - Typical CM_H Characteristics for 4 pin Transistor Optocouplers

If it is necessary to improve the overall CMTI performance, the following lines contain some useful information:

- If operating the phototransistor in transistor switch or emitter follower mode, the pull up resistor should be chosen to a low value (compare with figure 16)
- Overall a slow detector system behind the phototransistor may oversee the short time output signal distortion, due to the fact, that the distortions only appear during the transient change
- A low pass filter behind the output suppresses the fast transient distortion (sometimes the load capacitance C_L fulfills this task)
- To ensure a good CM_L behavior, it is recommended to operate the optocoupler in the saturated mode, which

means in this context to choose a high LED forward current.

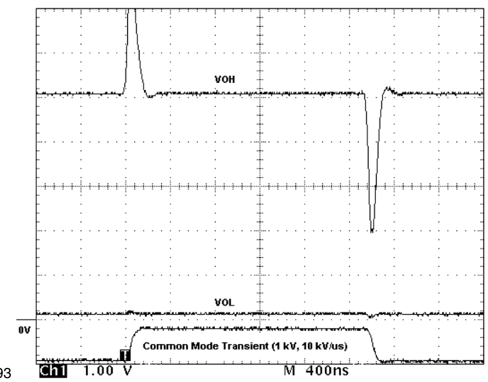

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Fig. 17 - Typical Behavior of a 4 pin Optocoupler During Excessive Common Mode Transients

4.2 Standard Optocouplers with External Base Contact

In general all optocouplers with external base contact have lower CMTI characteristics than their equivalent counterparts without external base contact.

In all devices it is in general a superposition of the two coupling paths - coupling directly to the output and coupling into the base/photodiode of the transistor via the coupling capacitances C_{CMO} and C_{CMB}.

Due to the strong influence of semiconductor parameters (compare especially with equation (8)), it is hardly possible to give a general curve which is valid for all optocouplers. Hence, figure 18 gives only a general information without claiming to be valid for every type.

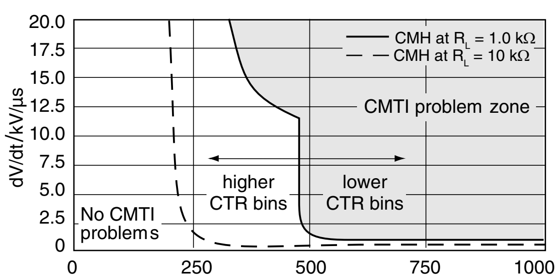

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Fig. 18 - Typical CM_H with $R_{BE} \rightarrow \infty$ Characteristics for 6 pin Transistor Optocouplers with External Base Connection

Optocouplers without external base contact do not cause distortions in slow/low pass systems as the nature of this distortion is a short transient (see section 4.1). Unlike these devices, couplers with external base contact also affect slow systems, because the transistor is really turned on or off. Thus the output signal distortion is present for some time and allows the following system to act (compare with figure 19). The performance at CML (LED on state) is very much based on the saturation of the transistor, and it is therefore hardly possible to present a general graph for CM_L.

If it is necessary to improve the overall CMTI performance of devices with external base connection, the following information might be helpful:

- The general rule is to use a device without base connection whenever possible
- If operating the phototransistor in transistor switch or emitter follower mode, the pull up resistor should be chosen to a low value (compare with figure 18)
- It is also recommended to choose low CTR binning types (compare with figure 18), because of their lower h_{FE}
- To ensure the good CM_L behavior, it is recommended to operate the optocoupler in the saturated mode, which means in this context to choose a high LED forward current.

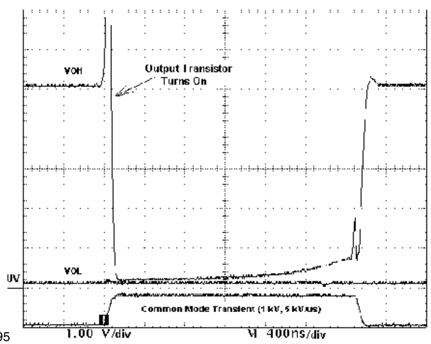

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Fig. 19 - Typical Behavior of a SFH600-3 During Excessive Common Mode Transients

Note that darlington optocouplers with external base have in general much lower CMTI characteristics due to their high amplification (h_{FE}).

4.3 The 1.0 MBit/s Optocouplers

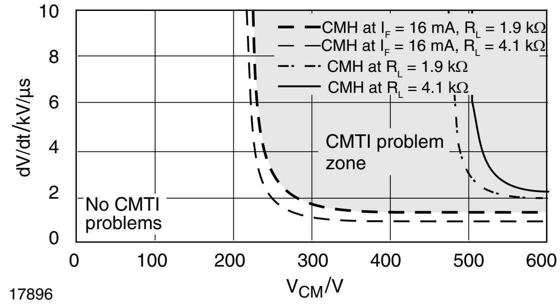
The 1.0 MBit/s family, the SFH6135/36 and the SFH6345 respectively their SO8 counterparts feature different CMTI specifications.

The SFH6135/36 series with the external base connection targets with the typical 1000 V/µs at 10 V specification into low end applications.

The SFH6345, the high end product, features a guaranteed minimum CMTI of 15 kV/µs at 1500 V.

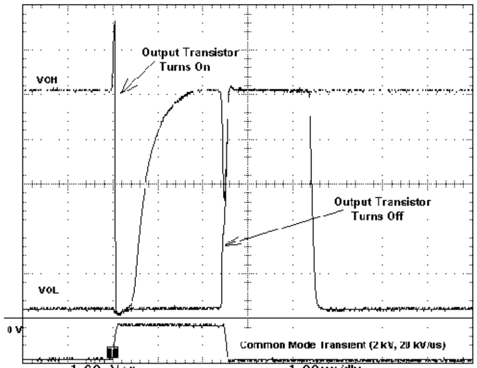
This differentiation makes sense due to different areas of applications.

Figures 20 and 22 show the difference between the low end and the high end product.



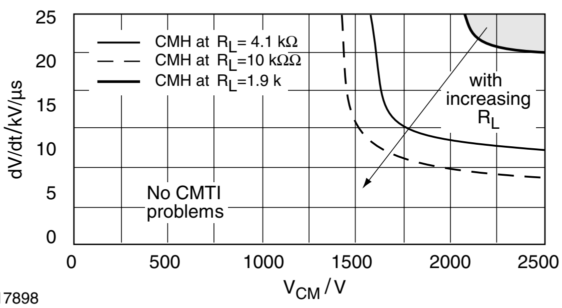
17896

Fig. 20 - Typical CMTI (CM_H and CM_L) Characteristics for the SFH6135/6136 Family of Fast Optocouplers



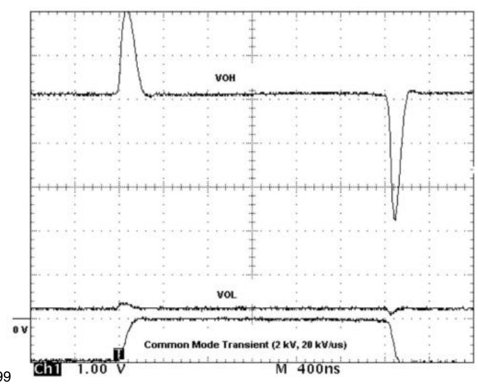
17897

Fig. 21 - Typical Behavior of a SFH6136 During Excessive Common Mode Transients



17898

Fig. 22 - Typical CM_H Characteristics for the High CMTI Rated Optocouplers



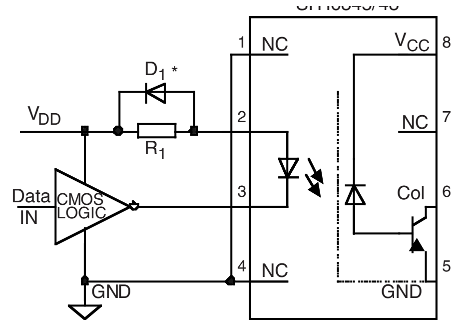
17899

Fig. 23 - Typical Behavior of a SFH6345 During Excessive Common Mode Transients

The above figures and graphs clearly show the advantage of the SFH6345/43 compared to the 'standard' product. To use this 'high end' product properly, here are some information which might be helpful:

- The pull up resistor should be chosen to a low value (compare with figure 22)
- Common mode transient immunity at logic low level is not an issue, if the optocoupler is operated in saturated mode (e.g. I_F = 16 mA, R_L = 1.9 kΩ)

A simple circuit which brings additional safety concerning CMTI is shown in figure 24. The circuit is component saving and works fine for this kind of devices.

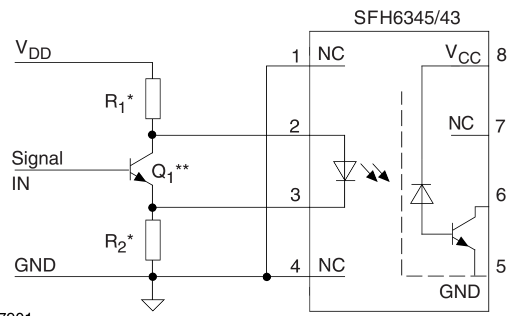


17900 * Diode D_1: any signaling diode

Fig. 24 - Input Circuitry for Improved CMTI

The diode D1 is intended to sink parasitic current, which is caused by stray capacitance, away from the LED to prevent a false turn on (reasonable value at V_{DD} = 5.0 V is 200 Ω for R_1).

A circuit for very high common mode immunity is presented in figure 25.



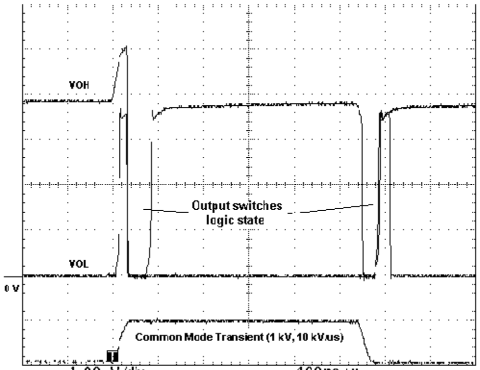
17901

Fig. 25 - Typical Input Circuitry to Achieve a Very High CMTI

In the schematic $R_1 = R_2$ (e.g. 100 Ω) represent the balanced input load. In the off-state the LED is shorted via Q_1 (e.g. 2N2222). Connecting the not used pins 1 and 4 to input ground potential reduces C_{ANO} and C_{CATH} substantially, which prevents the LED from a false turn on or off. The placing of the input circuit components is also very important - the tracks of the input circuit components and the anode with respect to cathode should be as short as possible, and designed with respect to reduce the possible stray capacitance to the detector side.

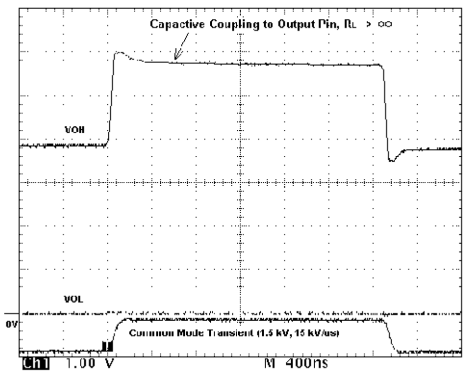
4.4 The 5.0 MBit/s Logic Gate Optocouplers

The 5.0 MBit/s family is divided into 2 groups, which feature different CMTI specifications. The low end products, the SFH670X withstand a common mode transient of 1000 V/µs at 50 V. For common mode transient affected applications the high end products, the SFH6711/12/19, are intended which feature a guaranteed CMTI of 2.5 kV/µs at 400 V. The higher rating is achieved by using the ITO shielding. This shield prevents the detector from being turned on or off by common mode transients. (refer to figures 26 and 27 for comparison).



17902

Fig. 26 - Worst Case Behavior of a SFH6700 (Low CMTI Rated Type) During Excessive Common Mode Transients (SFH6700, V_{CM} = 1.0 kV, dV/dt = 10 kV/µs)



17903

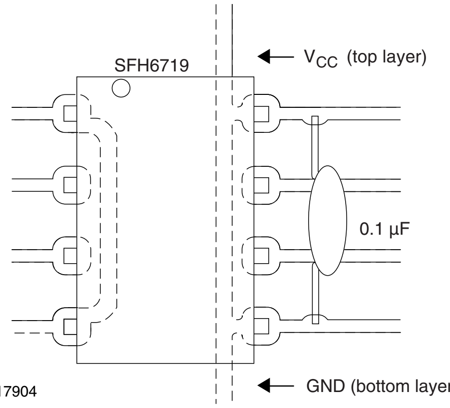
Fig. 27 - Typical Behavior of a SFH6719 (High CMTI Rated Type) During Excessive Common Mode Transients (SFH6719, V_{CM} = 1.5 kV, dV/dt = 15 kV/µs)

To use the high CMTI rated optocoupler properly, it is important to design the circuit around the optocoupler 'CMTI like', to achieve the full performance of the optocoupler.

In general there are some design rules to achieve this high CMTI. These recommendations are especially important for low LED drive current devices, like the SFH671X series:

- Connect the pins 1 and 4, which are not used to the virtually grounded input potential (either GND or V_{CC})
- Minimize stray capacitance
- Avoid long distances between LED input circuit and optocoupler
- Choose an appropriate high LED forward current to improve CM_H (common mode transient immunity at logic 'high' level)

A layout which keeps these hints in mind is seen in figure 28. Note that this layout reduces the creepage and clearance distance!



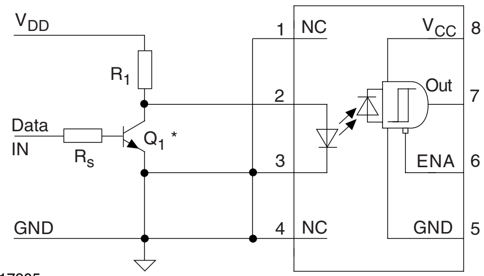
17904

Fig. 28 - Principle Board Layout for Enhanced CMTI (Fits to Schematic in Figure 29)

A circuit which brings additional safety concerning CMTI is shown in figure 29. The transistor shunts the LED in the off-state and prevents a false turn on. This circuit tolerates very high common mode transients in the LED off-state.

An improvement in the LED on-state can be reached by choosing a high I_F current.

For V_{DD} = 5.0 V, R_1 is typically around 1.1 kΩ.

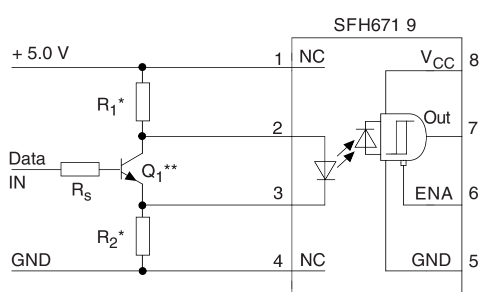


17905

* Transistor Q1: Any switching transistor (e.g. 2N2222)

Fig. 29 - Input Circuitry for High CMTI

A way to achieve ultra high CMTI is presented in figure 30. The balanced input impedance principle works with two resistors, $R_1 = R_2$. To achieve maximum performance, the stray capacitance from anode or cathode to the output side of the optocoupler has to be kept as low as possible. Reasonable values with Q_1 = 2N2222 are $R_1 = R_2$ = 510 Ω. Note that V_{CEon} ($V_{CE(SAT)}$) of the transistor Q_1 must be kept low to ensure that the LED is in the off state.



17906

* Resistor $R_1 = R_2$: to achieve a balanced input impedance

** Transistor Q_1: any switching transistor (e.g. 2N2222)

Fig. 30 - Input Circuitry for High CMTI

5. SYMBOLS AND ABBREVIATIONS

C_{ANO}	Capacitance anode-ground
C_{CATH}	Capacitance cathode-ground
C_{CMB}	Coupling capacitance LED - base/photodiode
C_{CMC}	Coupling capacitance LED - collector/output pin
C_{CE}	Capacitance collector emitter (detector)
C_L	Load capacitance
C_{BE}	Capacitance base emitter (detector)
C_{MTI}	Common mode transient immunity
CM_H	CMTI at logic high level
CM_L	CMTI at logic low level
dV/dt	Rate of voltage rise or fall
h_{FE}	Current gain
I_{ANO}	Current into the anode of the LED
I_{CATH}	Current into the cathode of the LED
I_B	Base current
I_C	Collector current
I_F	Forward current (LED)
R_L	Pull-up resistor, load resistor
t_r	Rise time
t_f	Fall time
ΔV_{CM}	Common mode transient voltage
V_{BE}	Base emitter voltage
V_{BEO}	Base emitter voltage at open collector
V_{OUT}	Output voltage level
V_{OH}	Output voltage at high level
V_{OL}	Output voltage at low lLevel