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Optical Sensors | Application Note

Designing the VCNT2020 Into an Application

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INTRODUCTION AND BASIC OPERATION

The VCNT2020 is a reflective sensor in a miniature SMD package with dimensions of (L x W x H in mm): 2.5 x 2 x 0.8. It has a compact construction where the emitting light source and the detector are arranged in the same plane, but the crosstalk from the IRED towards detector is almost zero. The operating infrared wavelength is 940 nm. The detector consists of a silicon phototransistor. The sensor's analog output signal (photo current) is triggered by the detection of reflected infrared light from a nearby object. The sensor has a built-in daylight blocking filter, which greatly suppresses disturbing ambient light and therefore increases the signal-to-noise ratio.

Typical applications are:

- Position sensor
- Optical switch
- Optical encoder (e.g. disc and tape drives for DVD and / or camera applications)
- Object detection (e.g. paper presence in printer and copy machines)

In comparison to other reflex sensors, such as the TCRT5000 with lenses above the IRED as well as the detector, the VCNT2020 may only be used for a detection distance up to 2.5 mm. Here at least about 20 % of the collector current is seen, and this only with an object that reflects all transmitted IRED light.

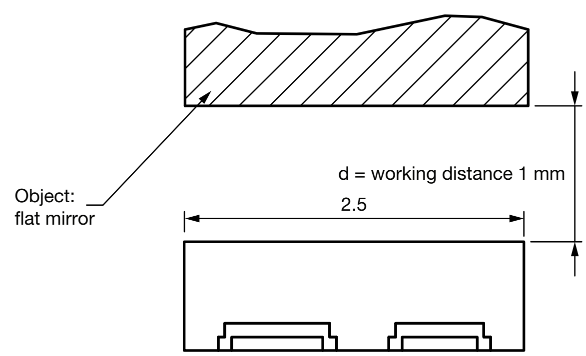


Fig. 2 - Test Circuit

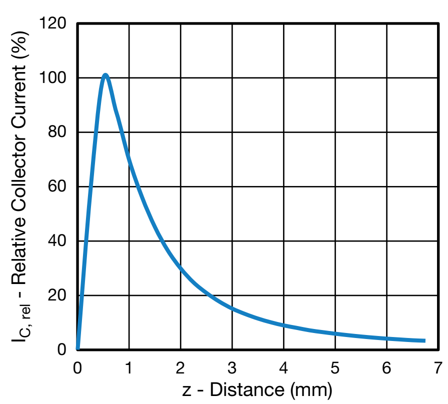
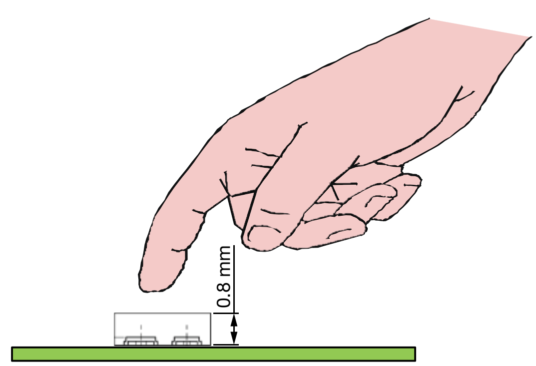


Fig. 1 - Relative Collector Current vs. Distance



Smallest Possible Reflector Sensor

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DATASHEET PARAMETER VALUES

The datasheet for each sensor includes the absolute maximum ratings, and electrical and optical characteristics. The absolute maximum ratings of the emitter, detector, and the sensor combined are provided. Maximum values for parameters like reverse and forward voltage, collector current, power dissipation, and ambient and storage temperatures are defined. The reflective sensors must be operated within these limits. In practice, applications should be designed so that there is a large margin between the operating conditions and the absolute maximum ratings. The electrical and optical characteristics indicate the performance of the sensor under specific operating conditions. Generally, the minimum and / or maximum values are provided. These values are guaranteed and are tested during the manufacturing of the sensor. Typical values, while sometimes provided, should only be used as a guide in the design process. They may or may not be tested during the manufacturing process and are not guaranteed.

For these reflective sensors, the ratio for collector current versus applied forward current is often defined as CTR. For the VCNT2020 this is typically seen with 8 %:

CTR = I_C/I_F = 1.6 mA/20 mA = 0.08, with a flat mirror used at a distance of 1 mm from the sensor.

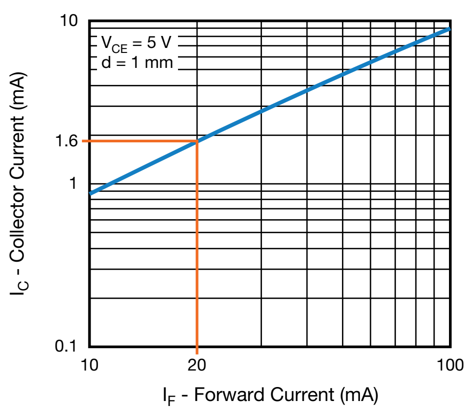

Fig. 3 - Collector Current vs. Forward Current

ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified)				
PARAMETER	**TEST CONDITION**	**SYMBOL**	**VALUE**	**UNIT**
INPUT (EMITTER)				
Reverse voltage		V_R	5	V
Forward current		I_F	100	mA
Forward surge current	$t_p \leq 100$ μs	I_{FSM}	500	mA
OUTPUT (DETECTOR)				
Collector emitter breakdown voltage		$V_{(BR)CEO}$	20	V
Emitter collector voltage		V_{ECO}	7	V
Collector current		I_C	20	mA
SENSOR				
Total power dissipation	$T_{amb} \leq 25$ °C	P_{tot}	170	mW
Ambient temperature range		T_{amb}	-25 to +85	°C
Storage temperature range		T_{stg}	-25 to +85	°C
Soldering temperature	In accordance with Fig. 11	T_{sd}	260	°C

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Within the basic characteristics table, the overall sensor data is shown with the emitter and detector data.

These are valid with the described test conditions, where a flat mirror is used at a distance of 1 mm from the sensor.

BASIC CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)						
PARAMETER	**TEST CONDITION**	**SYMBOL**	**MIN.**	**TYP.**	**MAX.**	**UNIT**
INPUT (EMITTER)						
Forward voltage	I_F = 20 mA	V_F	-	1.25	1.4	V
	I_F = 100 mA		-	1.5	1.7	
Temperature coefficient of V_F	I_F = 20 mA	TKV_F	-	-1.0	-	mV/K
Peak wavelength	I_F = 100 mA	λ_P	-	940	-	nm
Reverse current	V_R = 5 V	I_R	-	-	10	μA
OUTPUT (DETECTOR)						
Collector emitter breakdown voltage	I_C = 0.1 mA, E = 0	$V_{(BR)CEO}$	20	-	-	V
Emitter collector voltage	I_E = 100 μA, E = 0	V_{ECO}	7	-	-	V
Collector emitter dark current	V_{CE} = 5 V, E = 0	I_{CEO}	-	1	100	nA
SENSOR						
Collector current	V_{CE} = 5 V, I_F = 20 mA, d = 1 mm	I_C	0.5	1.6	3.5	mA
Current transfer ratio	I_C/I_F, d = 1 mm, V_{CE} = 5 V	CTR	-	8	-	%
Rise time	I_C = 0.8 mA, V_{CE} = 5 V, R_L = 100 Ω	t_r	-	10	70	μs
Fall time	I_C = 0.8 mA, V_{CE} = 5 V, R_L = 100 Ω	t_f	-	15	70	μs

In real applications, objects reflecting much less will often be used, and the load resistor added at the collector side will also be much higher.

How to define the needed emitter current and possible load resistor is shown within the following example calculations.

Tests with the worst reflecting objects need to be performed in order to examine the behavior and decide for the correct circuitry, emitter current, and load resistor.

For all parameters, the limits always need to be seen and not the typical values.

The typical relationship between collector current and distance needs a defined reflective object, which here is a flat mirror showing almost 100 % reflectivity.

The peak for reflected light is at about 0.5 mm.

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DISTANCE BETWEEN SENSOR AND OBJECT

The phototransistor collector current is also dependent on the distance of the reflecting material from the sensor. Fig. 3 shows the relative collector current versus the distance of the material from the sensor for the TCRT1000. This curve is included in each reflective sensor datasheet. The data was recorded using the Kodak neutral card's 90 % diffuse reflecting surface. The distance was measured from the surface of the sensor. The emitter current, I_F, was held constant during the measurement.

This curve is called the working diagram. The working diagram of all reflective sensors shows a maximum collector current at a certain distance. For greater distances, collector current decreases. The working diagram is an important input to the reflective sensor circuit design. Choosing an operating distance at or near the sensor's maximum collector current will provide greater design flexibility.

REFLECTION INDEX OF VARIOUS MATERIALS / COLORS			
Kodak Neutral Card		**Plastics, Glass**	
White side (reference medium)	100 %	White PVC	90 %
Gray side	20 %	Gray PVC	11 %
Paper		Blue, green, yellow, red PVC	40 % to 80 %
Typewriting paper	94 %	White polyethylene	90 %
Drawing card, white (Schoeller Durex)	100 %	White polystyrene	120 %
Card, light gray	67 %	Gray partinax	9 %
Envelope (beige)	100 %	**Fiber Glass Board Material**	
Packing card (light brown)	84 %	Without copper coating	12 % to 19 %
Newspaper paper	97 %	With copper coating on the reverse side	30 %
Pergament paper	30 % to 42 %	Glass, 1 mm thick	9 %
Black or White Typewriting Paper		Plexiglass, 1 mm thick	10 %
Drawing ink (Higgins, Pelikan, Rotring)	4 % to 6 %	**Metals**	
Foil ink (Rotring)	50 %	Aluminum, bright	110 %
Fiber-tip pen (Edding 400)	10 %	Aluminum, black anodized	60 %
Fiber-tip pen, black (Stabilo)	76 %	Cast aluminum, matt	45 %
Photocopy	7 %	Copper, matt (not oxidized)	110 %
Plotter Pen		Brass, bright	160 %
HP fiber-tip pen (0.3 mm)	84 %	Gold plating, matt	150 %
Black 24 needle printer (EPSON LQ-500)	28 %	**Textiles**	
Ink (Pelikan)	100 %	White cotton	110 %
Pencil, HB	26 %	Black velvet	1.5 %

Note
- Relative collector current (or coupling factor) of the reflex sensors for reflection on various materials. Reference is the white side of the Kodak neutral card. The sensor is positioned perpendicular to the surface. The wavelength is 950 nm

INTRODUCTION EXAMPLE CALCULATION

To get a reliable application with regard to the tolerances, the calculation should be based on the minimal collector current.

Because the minimum I_C is not available for d = 0.5 mm it is necessary to calculate the min. I_C for the distance 0.5 mm based on the min. I_C at d = 1 mm.

According to Fig. 1 the I_C is reduced by 30 % at a distance of 1 mm.

The min. I_C at d = 0.5 mm can be calculated as follows:

I_C min. = 1.3 x I_C min. (at d = 1 mm)

This leads to an I_C min. of ≥ 0.65 mA at d = 0.5 mm.

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EXAMPLE CALCULATION (1)

The sensing distance should be 2 mm. The object is highly reflective: > 90 %. According to Fig. 1, just about 30 % of the collector current will be present than what is seen at about 0.5 mm.

To get sufficient collector current the forward current needs to be high enough, I_F = 20 mA is chosen here.

As in the introduction already calculated the min. I_C at d = 0.5 mm is I_C = 0.65 mA. At a distance of 2 mm the I_C is reduced by 70 %. compared to the I_C that occur at d = 0.5 mm.

This leads to a min. I_C at d = 2 mm of $I_C \geq$ 0.2 mA.

Simple Application Circuitry

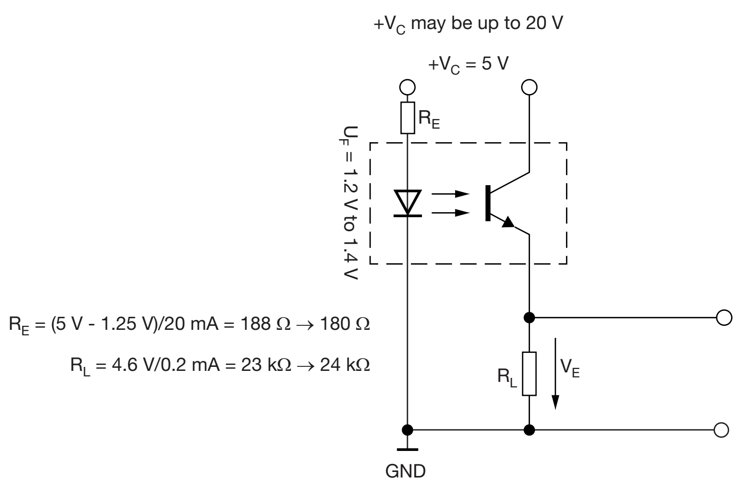

Fig. 4 - Application Example (1)

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EXAMPLE CALCULATION (2)

The sensing distance should be 5 mm. The object is highly reflective: > 90 %. According to Fig. 1, just about 5 % of the collector current will be present at 0.5 mm.

With a I_F = 40 mA the min. I_C value at d = 0.5 mm is now twice the value at I_F = 20 mA which accordingly leads to a min. I_C of 1.3 mA at d = 0.5 mm.

With the reduction by 95 % at d = 5 mm of the I_C that occur at d = 0.5 mm this leads to a min. I_C of 0.065 mA.

Simple Application Circuitry

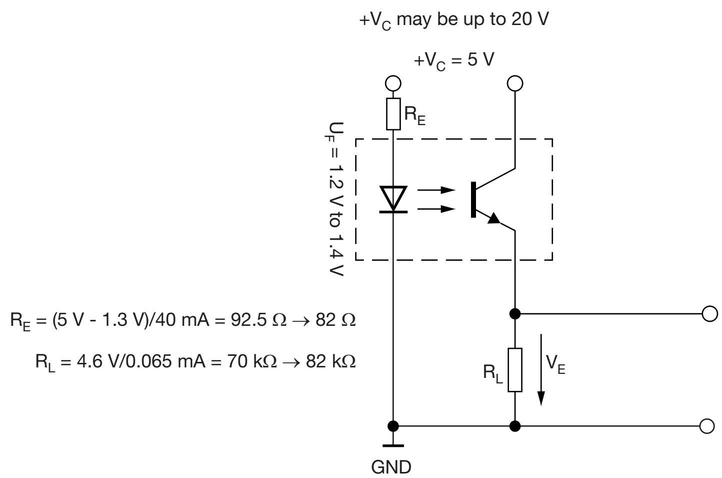

Fig. 5 - Application Example (2)

This is quite high-ohmic and could also lead to high sensitivity for disturbing light sources.

To avoid problems here, one should chose a lower load resistor even if one needs to add an additional transistor behind (please see the next example).

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EXAMPLE CALCULATION (3)

If the reflectivity of the object is just ≥ 35 % (e.g. skin / hand) and the desired sensing distance is 2 mm, then the load resistor would be getting quite high-ohmic and this also with a forward current of I_F = 40 mA.

I_C min. at a distance of 2 mm is twice as high when the emitter is driven with an I_F of 40 mA. Accordingly this leads to an min. I_C of 0.4 mA at d = 2 mm. This is again reduced due to bad reflectivity of just ≥ 35 %. So, just 0.4 mA - 65 % ≥ 0.14 mA.

If wished output voltage should also be ≥ 4.6 V, the load resistor would get quite high-ohmic:

Simple Application Circuitry

R_E = (5 V - 1.3 V)/40 mA = 92.5 Ω → 82 Ω

R_L = 4.6 V/0.14 mA = 32.9 kΩ

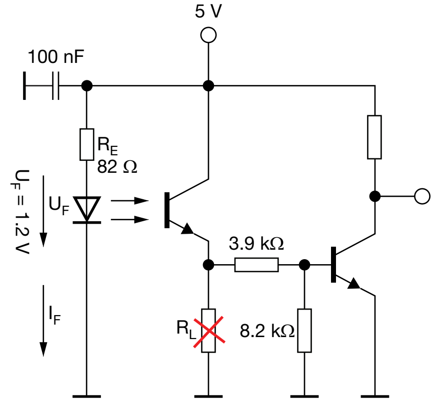

Fig. 6 - Application Example (3)

This is not a problem, even with the highest specified dark current of 100 nA, which would lead to just 100 nA x 32.9 kΩ = 3.29 mV, but disturbing light sources will see a quite sensitive detector.

Adding just a simple transistor here would improve the circuitry, as now one would only need just ≥ 1 V to switch, even with a resistor divider.

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DERATING AND TEMPERATURE BEHAVIOR

The VCNT2020 is specified for a temperature range of -25 °C up to 85 °C, where - if operation above 45 °C is also needed - the emitter current needs to be decreased.

Within characterization tests, determining the thermal resistance and using an I_C = 15 mA, $T_{j\ max.}$ of 93 °C is seen.

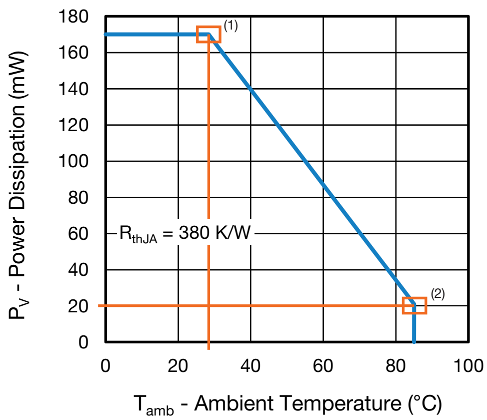

Fig. 7 - Power Dissipation vs. Ambient Temperature

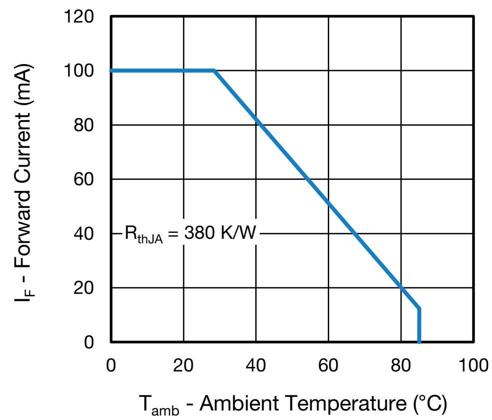

Fig. 8 - Forward Current vs. Ambient Temperature

Notes

(1) Used formula: T_{amb} = 93 °C - R_{thJA} x P_{tot} (with P_{tot} = 0.17 W, R_{thJA} = 380 K/W) → T_{amb} = 28.4 °C

(2) Used formula: 93 °C = 85 °C + R_{thJA} x P_{tot} → P_{tot} = 21.05 mW

The variance of the collector current vs. temperature range between -25 °C and +85 °C is about ± 25 %.

For higher temperatures, the dark current also increases. This may end up at nearly 1 μA at 85 °C. This needs to be kept in mind when choosing a quite high-load resistor.

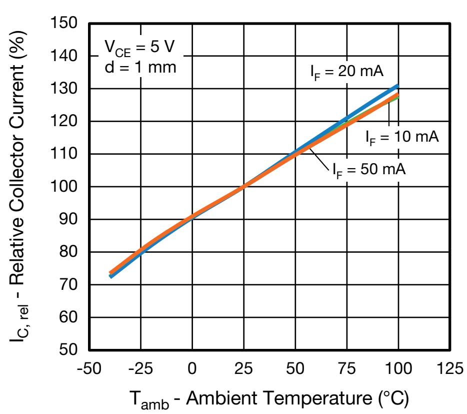

Fig. 9 - Relative Collector Current vs. Ambient Temperature

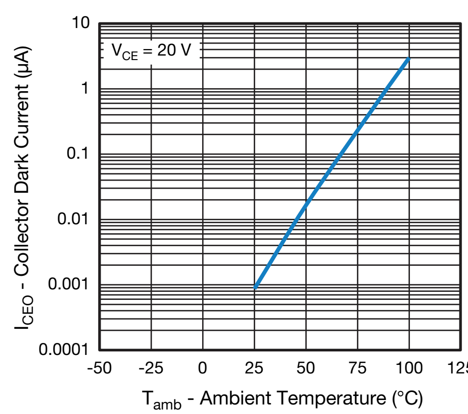

Fig. 10 - Collector Dark Current vs. Ambient Temperature

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SWITCHING TIMES

Rise and fall times are defined to be less than 70 μs, typical t_r = 10 μs and t_f = 15 μs.

But this is seen with a very low load resistor of just 100 Ω, so, also a higher collector current of ≥ 1 mA.

To allow for such a low-load resistor, additional amplification may be needed, as shown in Fig. 6.

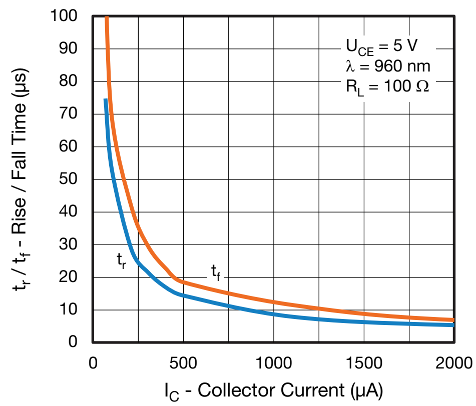

Fig. 11 - Rise / Fall Time vs. Collector Current

SENSITIVITY TO DISTURBING LIGHT SOURCES

Although the sensor has a built-in daylight blocking filter, which greatly suppresses disturbing ambient light and therefore increases the signal-to-noise ratio, bright sunlight will influence the sensor.

A higher forward current plus lower collector load resistor will help here, but might not for very strong light sources also containing high infrared signals.

A possible solution could be not to operate the emitter continuously, but pulsed.

Having DC-decoupling amplification at the collector side would also eliminate this more steady signal.

As a good side effect, either the current consumption would be lower or higher peak current would be allowed, resulting in higher detection distances.

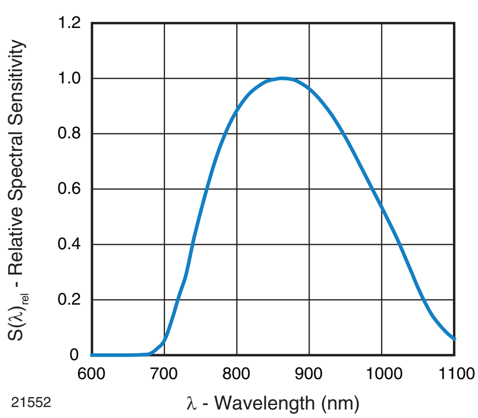

Fig. 12 - Relative Spectral Sensitivity vs. Wavelength

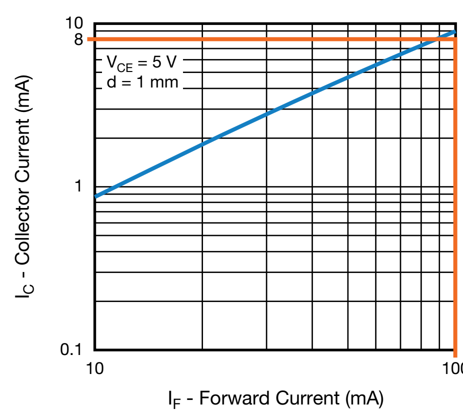

Fig. 13 - Collector Current vs. Forward Current

APPLICATION NOTE

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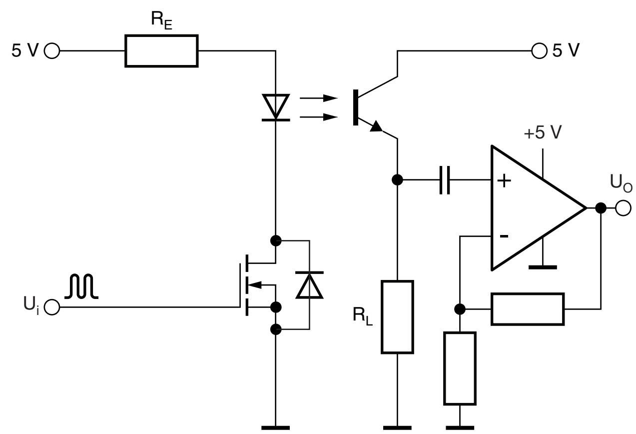

Fig. 14 - Application Example With Added AC-Coupled Amplification

For technical questions, contact: sensorstechsupport@vishay.com