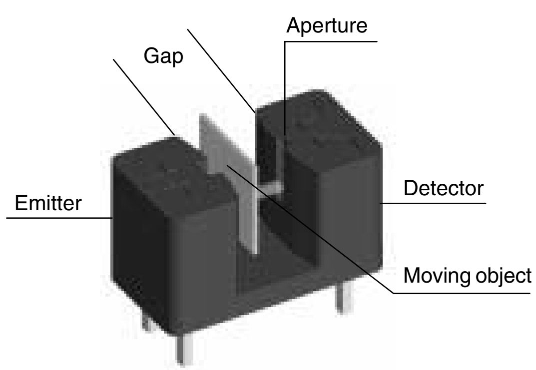
Application of Optical Sensors

Optical Transmissive and Reflective Sensors

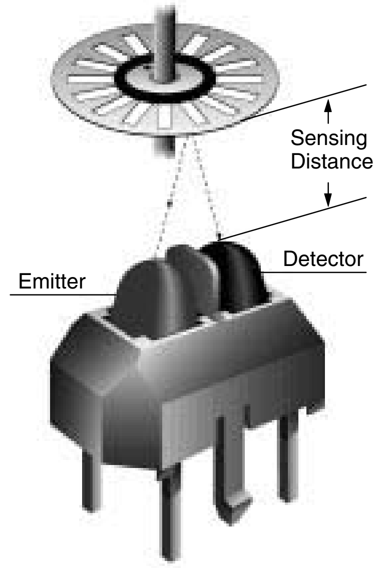
- Optoelectronic transmitters and receivers are used in pairs and linked optically
- Known as transmissive sensors or interrupters or slotted switch or optical switch or reflective sensors
- Emitting light is influenced by an object on its way to the detector
- Change of the light signal causes a change in the electrical signal in the receiver

Transmissive Sensors:
Transmitter is positioned opposite the receiver used for small distances and narrow objects



18558

Reflective Sensors:
Transmitter is positioned next to the receiver used for a wide range of distances objects of different shapes



18559

Majors Criterions:
- Housing material
- Lead Distance
- Ambient light protection
- Aperture (defines the resolution of the Transmissive Sensor)
- Gap (Referring to thickness of object)
- Reflecting distance between Reflective Sensor and Object

Optical Transmissive Sensors

The basic elements of an optical transmissive sensor also known as Photo interrupter are an emitter and a photo detector. Typically an IRED (Infrared emitting diode) and a Phototransistor is used. Figure 2 shows a typical circuit.

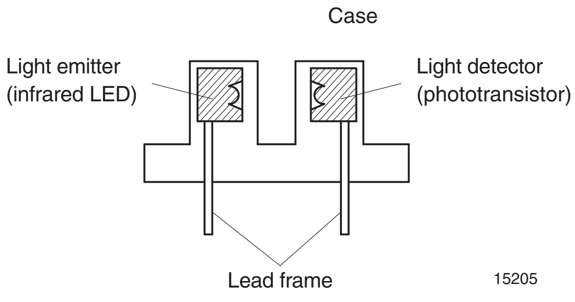


Figure 1.

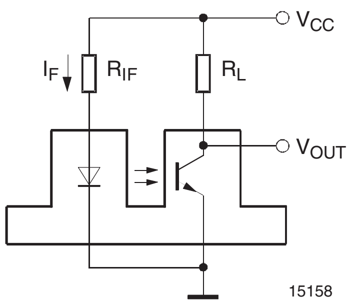


Figure 2.

The anode of the IRED is connected to the power supply via the resistor R_{IF} and the cathode is grounded. The resistor adjusts the irradiance by limiting the forward current of the IRED. The collector of the phototransistor is also connected to the power supply via the resistor R_L and the emitter is grounded. The output pin can be connected to a the next stage like an analog amplifier, comparator or Schmitt-Trigger. If an object is moving towards the aperture the light will be blocked and the collector current decreases as shown in figure 2. If the object is moving away from the aperture again the collector current increases in the same manner. With this method an object can be detected without any mechanical or electrical contact. The output signal of the sensor can be processed by the subsequent circuitry to control the various functions.

Important Diagrams

Collector current vs. distance

The resolution of an optical transitive sensor depends on the aperture, the light sensitive area of the detector and the direction of movement. The object should have no IR translucence to increase performance. For linear position sensing applications only the range from 90 % to 10 % can be used.

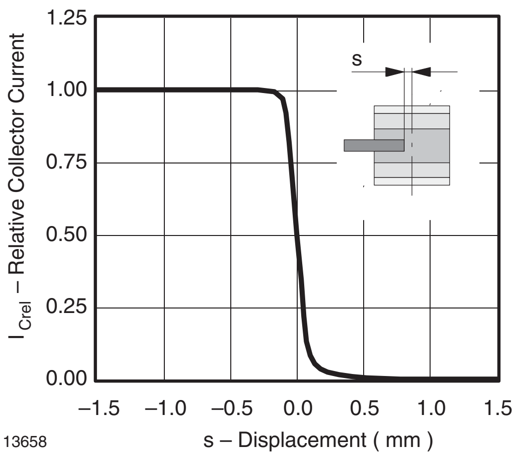


Figure 3.

Collector current vs. forward current

The relation between output collector current and input forward current is called CTR (current transfer ratio).

$$CTR = \frac{I_C}{I_F} \times 100(\%)$$

The CTR can be the same for the combination of a high power emitter and a less sensitive detector or for a high sensitive detector with a lower power emitter. The CTR changes over temperature, lifetime and contamination of the apertures.

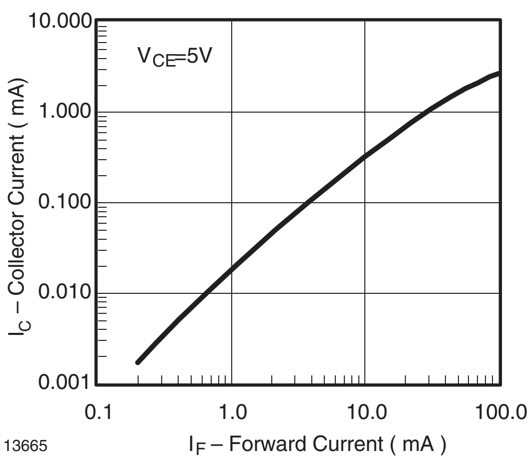


Figure 4.

CTR vs. temperature

The variation of the CTR is caused by the decreasing radiant intensity of the emitter (– 1 %/ °C) and the increasing sensitivity of the detector (+ 0.3 %/ °C) over the temperature. By matching the technologies of the emitter and the detector it's possible to compensate this effect at least for a certain temperature range.

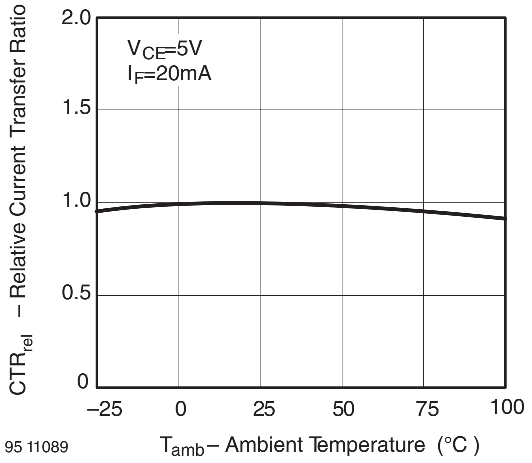


Figure 5.

Total power dissipation vs. temperature

The absolute power dissipation of the sensor or of the single elements is very important for the design of the application. The application should never exceed these values to avoid damage or even destruction of the sensor device.

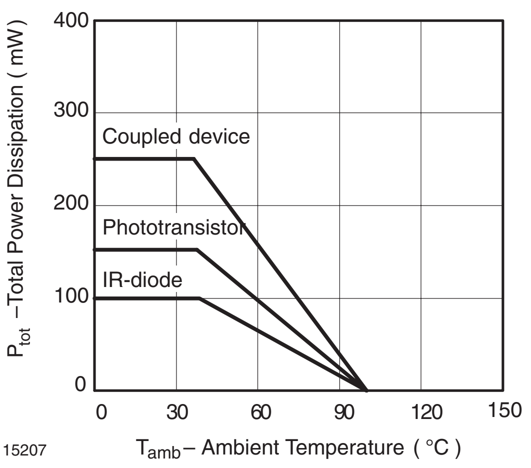


Figure 6.

CTR vs. operation time

Over long operation times, the current transfer ratio drops. This is mainly caused by the lower radiant intensity of the emitter. This fall must be considered during application design.

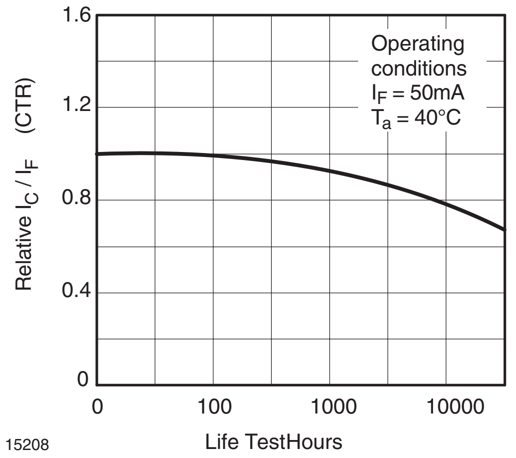


Figure 7.

Basic Application Circuits

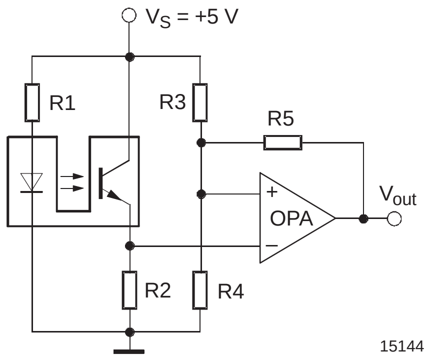


Figure 8. Circuit with voltage comparator

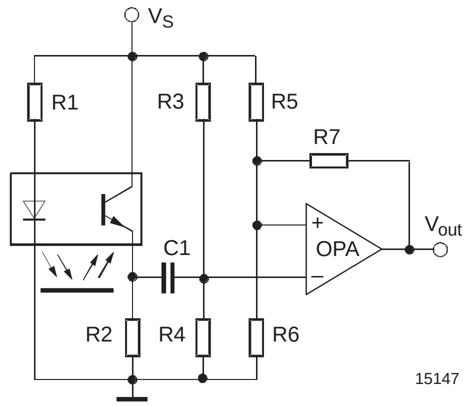


Figure 11. Circuit with OPA AC coupling

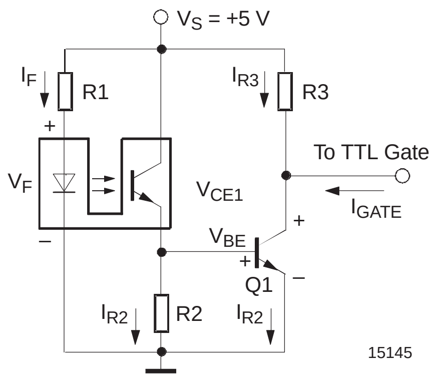


Figure 9. Circuit with a additional transistor

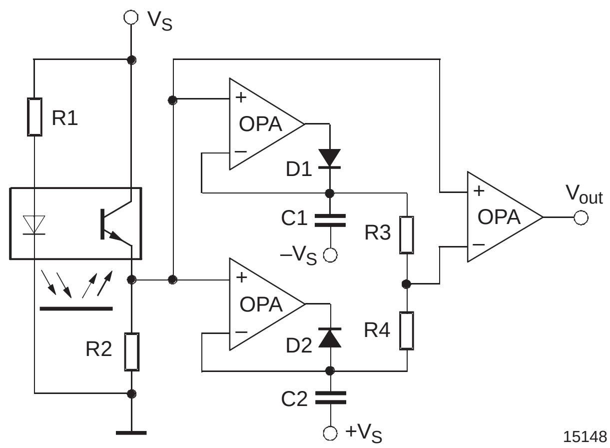


Figure 12. Circuit with floating comparator

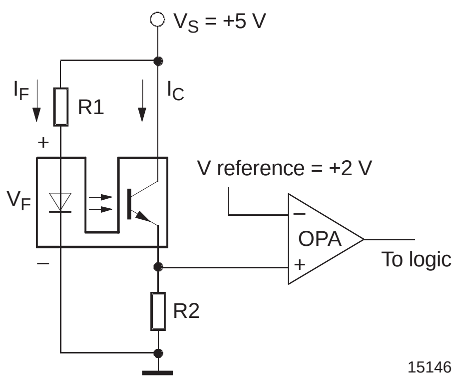


Figure 10. Circuit with operation amplifier

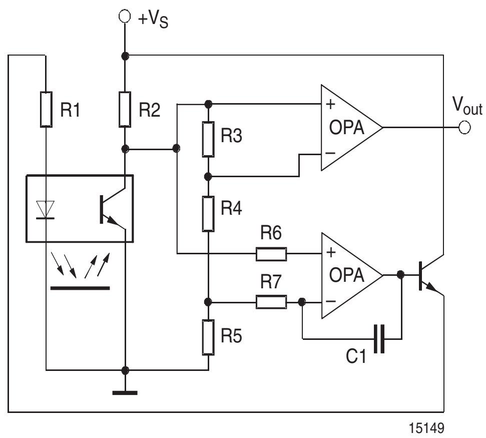


Figure 13. Circuit with emitting light compensation

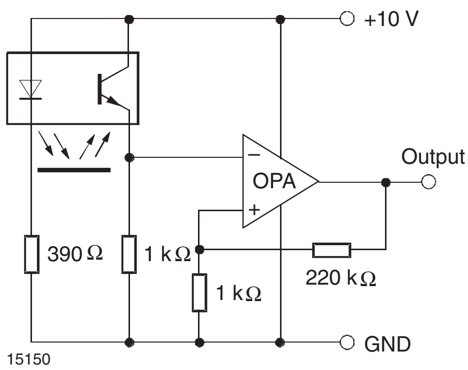


Figure 14. Circuit with operation amplifier

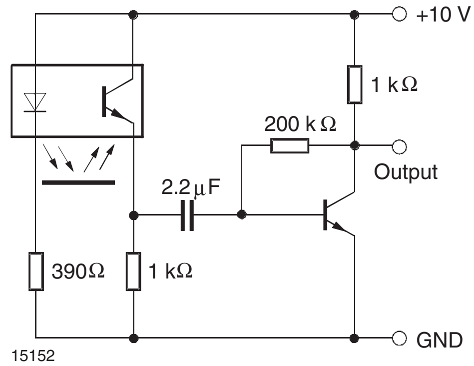


Figure 16. Circuit with transistor amplifier

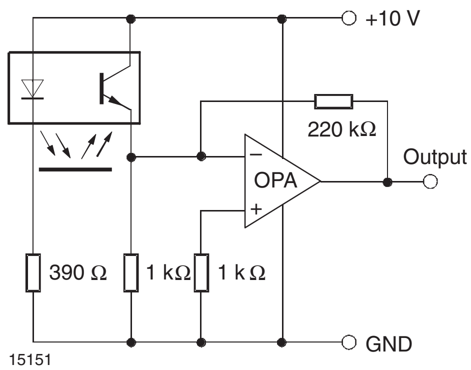


Figure 15. Circuit with operation amplifier

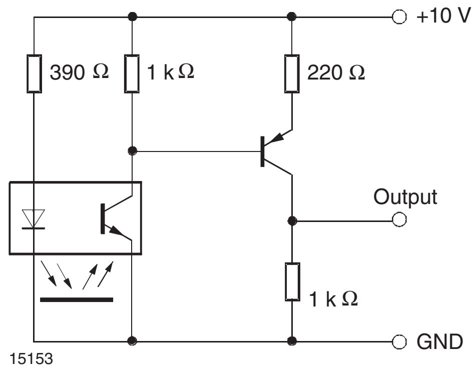


Figure 17. Circuit with transistor amplifier

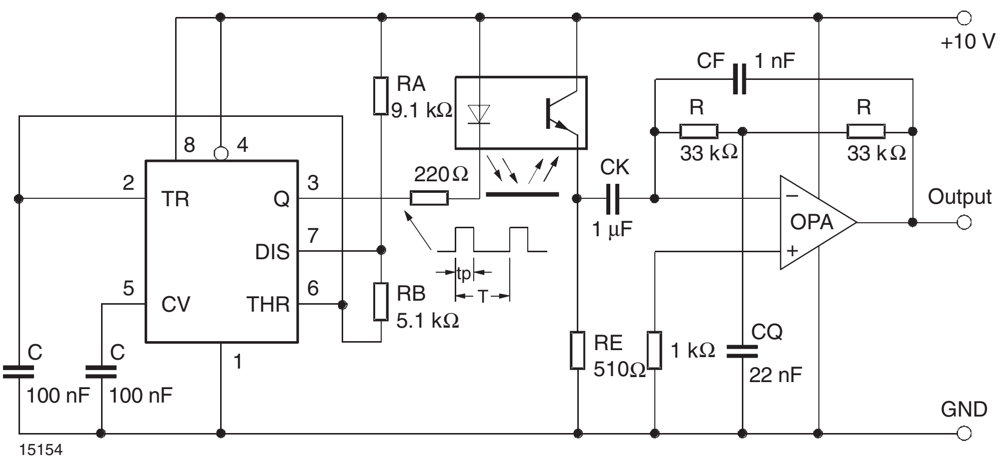


Figure 18. Circuit with AC coupling and oscillating to suppress the ambient light

How to find the optimum working points for your application:

During the design phase of the application, the working point of the sensor must be defined.

A basic design rule is:

- Higher emitter forward current increases performance but limits lifetime and maximum operation temperature.

The typical forward current of a standard optical transmissive sensor is in the range of 5 to 30 mA. The design should consider the condition changes over lifetime, contamination and temperature and the device variation itself. All calculations of course should be based on the worst case conditions.

To avoid damage or even destruction of the device the design should never exceed the maximum power dissipation of the sensor.

The maximum power dissipation of the sensor is calculated:

$I_{F\ max}$ = forward current in your application

$T_{amb\ max}$ = maximum ambient temperature of the application

$V_{F\ max}$ = maximum forward voltage of the emitter

Emitter:

$P_{tot} = I_F \times V_{Fmax}$

$P_{tot} < P_{tot}$ @ $T_{amb\ max}$ = ok

Detector:

$P_{tot} = I_C \times V_{CEsat\ max}$

$P_{tot} < P_{tot}$ @ $T_{amb\ max}$ = ok

To provide function over the whole application temperature range and long lifetime, the design must consider some additional limits.

At high and low temperatures and long operation times the CTR value drops.

In total this can add up to 50 % of the initial value at 25 °C.

The best way to solve this problem is to increase the load resistor value if the next stage circuitry level requirements can be met.

If not, increasing the forward current is also a suitable method but the sensor stability over the operation time depends mainly on the degradation of the emitter which again depends on the forward current. (Higher forward current –> shorter lifetime). So a higher load resistor should be the preferred solution.

Contamination also decreases the CTR value and must be considered in the application by own judgement.

The optimal load resistor value is in a range where the output is 3 – 10 times saturated.

Choosing a very high load resistor can cause an output voltage change from the quiescent current only.

Basically the quiescent current is the sum of the dark current and the collector current from the ambient light.

In switching applications the quiescent current mainly is negligible but in a linear position sensing application the quiescent current at high temperatures and un-shielded ambient light can cause poor position sensing accuracy.

Max. load resistor:

$R_{L\ max} = I_{Quiescent} \times V_{Drop\ max}$

$I_{Quiescent} = I_{Dark\ max}$ @ $T_{amb\ max}$

I_C caused by ambient light

$V_{Drop\ max}$ = maximum allowed voltage drop from next stage circuitry

A too low dimensioned load resistor can cause a collector current that is not high enough to obtain the maximum possible voltage swing (especially over long operation time and temperatures changes).

Min. load resistor:

$R_{L\ min} = I_{C\ min} \times V_{Drop\ min}$

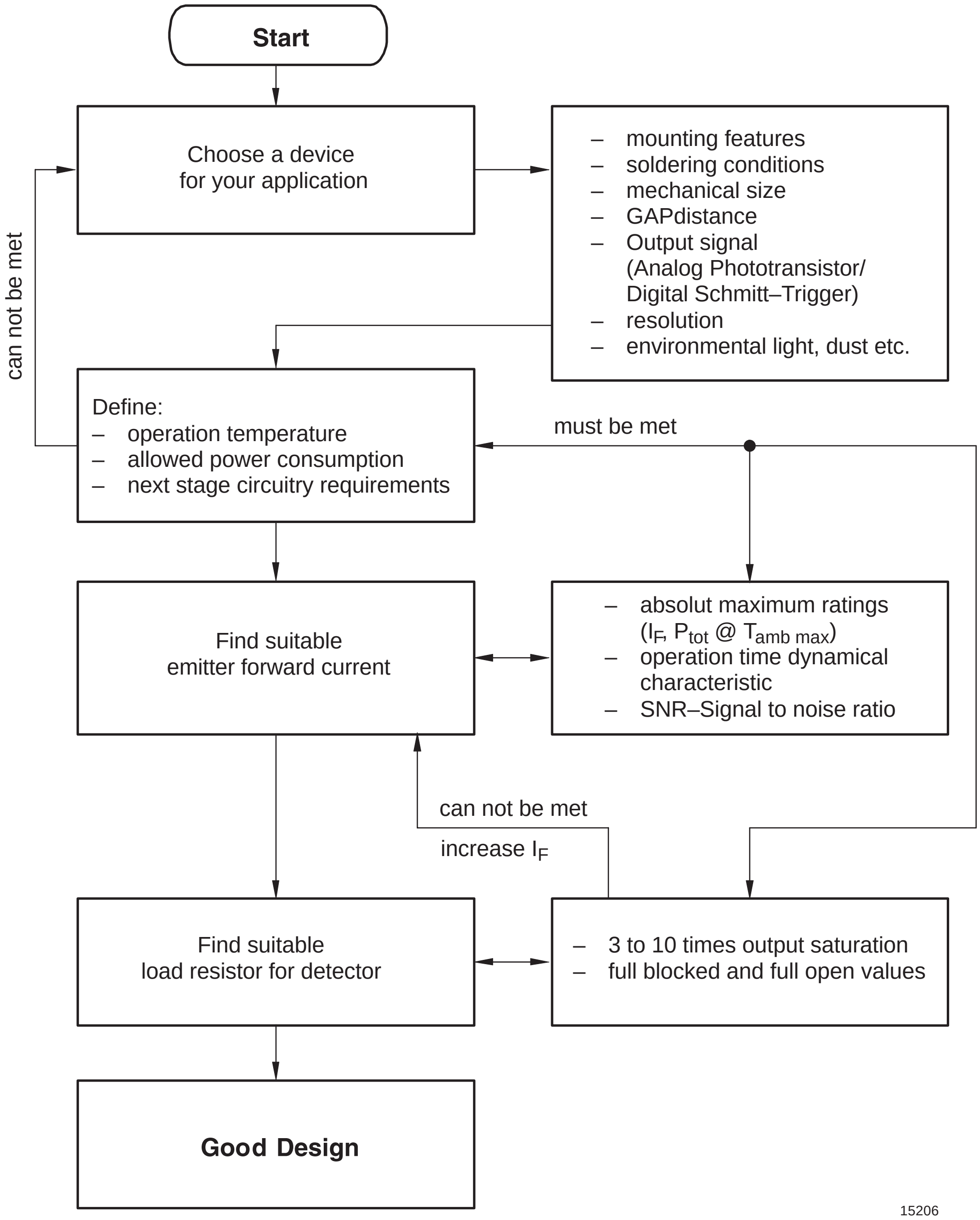
$I_{C\ min}$ [1)] = min. collector current @ $T_{amb\ max}$

$V_{Drop\ min}$ = minimum voltage drop from next stage circuitry

[1)] I_C min must also consider lifetime & contamination

Document number: 80108
Rev. 1.2, 03-Dec-03

Design Flow Chart

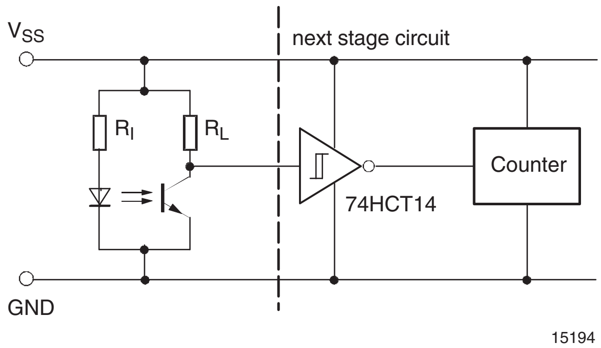


Typical applications for optical transmissive sensors

The sensor must detect a true passing object to count the quantity. The object width is 0.5 mm. The following conditions must be observed:

- Power dissipation 9 60 mW
- Operation temperature – 40 °C to + 80 °C
- V_{SS} = 5 V
- Output must be CMOS compatible:
  high ≥ 2/3 V_{SS}
  low ≤ 1/3 V_{SS}
- Output logic:
  Object = high
  non object = low

A possible circuitry solution:



The TCST 1102 has an aperture size of 0.5 mm. This means that the aperture can be totally covered by the object which provides maximum dynamic. The typical CTR (current transfer ratio) of this sensor is 10 % so for the first rough calculation the maximum allowed power consumption of 60 mW can be divided into 90 % for the emitter and 10 % for the detector.

At a V_{SS} of 5 V the total allowed current is 12 mA so the emitter current is about 11mA and the resulting collector current about 1 mA.

The next step is to check if the calculated results exceed any limits.

The most critical limit is the total power dissipation of the sensor.

Emitter:

$P_{tot} = I_F \times V_{Fmax}$

Detector:

$P_{tot} = I_C \times V_{CEsat\ max}$

To simulate the worst case conditions, the forward Voltage of the emitter should be $V_{F\ max}$ of the in the data sheet. The same for the collector saturation voltage $V_{CEsat\ max}$ of the detector If the calculated power dissipation are within the limits, the next step is the resistor calculations. In this case the typical V_F of the emitter should be taken.

$$R_I = \frac{V_{SS} - V_{FTyp}}{I_F}$$