Sharp GP2DO2 - a sensor for distance depending control

Description and application of a simple distance measuring system

C l a u s K ü h n e l

If the simple Yes/No decision of a light barrier or a proximation circuit as an answer of monitoring is not sufficient than the distance measurement can deliver additional information. Simple systems for distance measurement should be not more expensive as light barrier systems. In this article Sharp's position sensitive photo detector GP2DO2 will be described relating to function and application.

The sensor GP2DO2 contains an infrared transmitting diode, a position sensitive photo detector, some optics and a signal processing unit in a compact casing of 29 x 14 x 14,4 mm^3. Only four pins give the electrical contact to the sensor. Two of them are power supply and the other two builds a simple serial interface for the data handling during the measurement. Fig. 1 gives an impression of the Sharp's sensor GP2DO2.

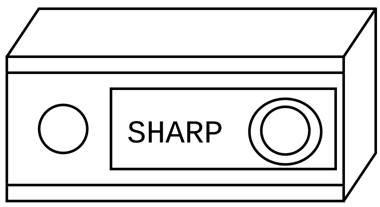

Fig. 1 Sharp's GP2D02 for distance measurement

On the left side of the case there is the IR LED and on the right side is the position sensitive photo detector behind an optical lens. The method of distance measurement is very simple. Fig. 2 shows the method.

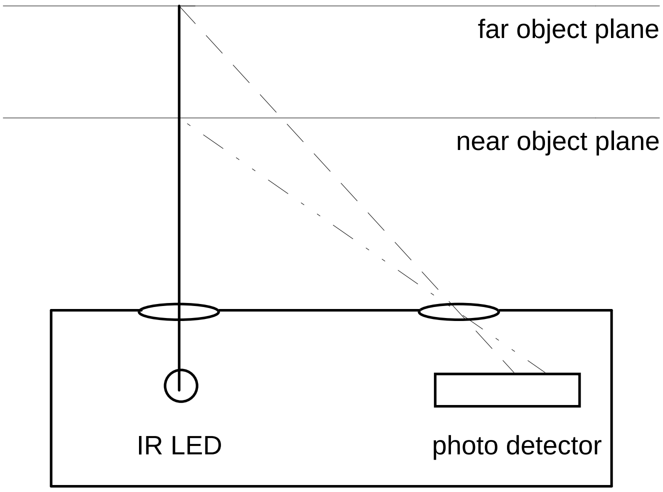

Fig. 2   Distance measurement by triangulation

The IR LED transmits a bundled beam to the object plane to be measured. From the photo detector a reflected beam will be received. The angle of the received beam is dependant of the distance of the object plane. For two different object planes the situation is displayed in Fig. 2. If the photo detector is able to process a position sensitive input signal then there is an information of the distance of an object given.

Photo diodes with a big light sensitive area have position sensitivity on principle. Based on this physical effect there was position sensitive photo detectors developed. Fig. 3 displays the principle of a position sensitive photo diode.

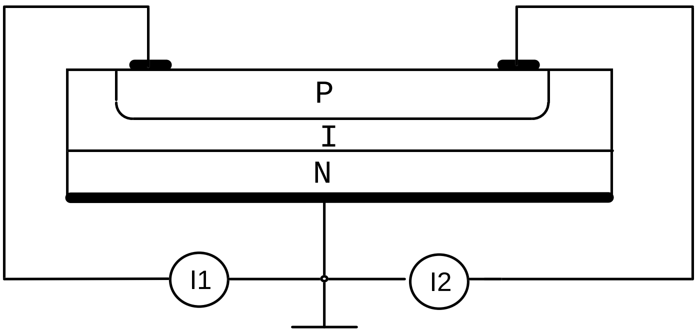

Fig. 3 Structure of a position sensitive photo diode

The vertical structure of the position sensitive photo detector is identically to the structure of general pin diodes. Based on a n-conductive substrate layer is an isolation layer. Embedded in this isolation layer is the p-conductive layer from IR irradiated. The contacting of the p-layer (anode) is made on the left and on the right side.

If there is a spot irradiation in the centre of the p-layer then both currents I1 and I2 will have the same value. If the spot irradiation goes to the left the current I1 wills grow and the current I2 will drop with the same value. The difference between the currents I1 and I2 describe the location of a spot irradiation on the light sensitive surface (between the contacts) of the position sensitive photo diode.

To process the measured distance the signal processing unit has to exploit the difference in the currents I1 and I2. After an analog-to-digital conversion the result of measurement is ready for serial transmission to a microcontroller or other processing unit.

For the processing of optical signals comparable conditions are valid:

- The daylight (or the light of the environment in more general terms) may not influence the measuring procedure.
- Related to distance and reflection of objects to be measured the reflection behaviour of these objects shows strong changes in value.
- The very high dynamic range of the measuring signal requires signal compression for working with normal voltages for power supply.

Disregarding special circuit techniques in bipolar integrated circuit technology (like I^2L) that convert an irradiation into a digital signal directly than one can find circuits based on logarithmic current-to-voltage converters always again. For logarithmic current-to-voltage converters there are excellent technological solutions with a very good performance.

Fig. 4 shows the principle of a circuit for position sensitive current-to-voltage conversion.

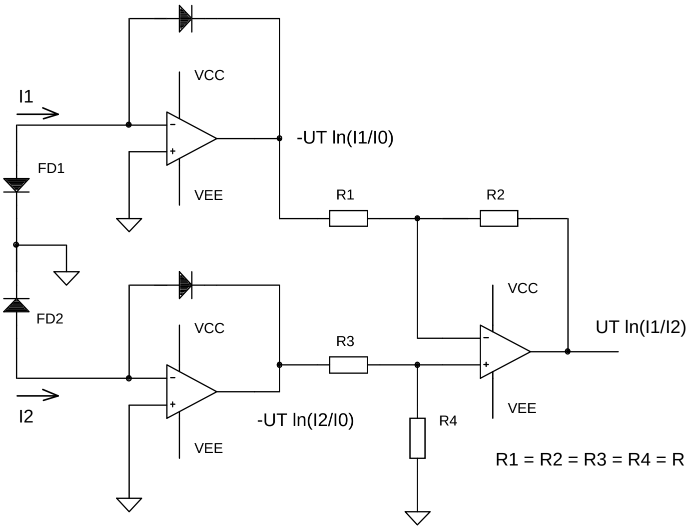

Fig. 4 Circuit for position sensitive current-to-voltage conversion

In Fig. 4 the position sensitive photo detector is described through the photo diodes FD1 and FD2. Both anodes are connected with identical circuits for current-to-voltage conversion. The diodes in the opamp's feedback give a logarithmic behaviour of the current-to-voltage conversion.

To achieve the required accuracy the diodes are build by bipolar transistors with a grounded base. In a good approach the following equation is valid:

$$I_C \cong I_0 \cdot \exp\left(\frac{V_{BE}}{V_T}\right) \qquad (1)$$

V_T describes the temperature voltage proportional to the absolute temperature by eq. (2)

$$V_T = \frac{kT}{e} \quad \text{with k = Boltzmann's constant and e = elementary charge} \qquad (2)$$

I_0 describes very strong temperature dependant saturation current of the bipolar transistor.

For the output voltage of the logarithmic current-to-voltage converter the following equation is valid:

$$V_O = -V_T \ln(\cdot \frac{I_C}{I_0}) \quad (3)$$

The collector current IC is identically to the current I1 in the upper circuit part of fig. 4 and to I2 in the lower part. The third opamp processes the difference of the two output voltages. There is only one condition for accuracy - the resistor values have to be equal.

The output signal of the third opamp is described by eq. (4):

$$V_O = V_T \cdot \ln(\frac{I_1}{I_2}) \quad (4)$$

The influence of the saturation current I_0 is cancelled in eq. (4). It remains only the influence of the temperature voltage. Because this influence is linear it can be eliminated easily. Changes of intensity (daylight) will be suppressed because they affect both currents. For further digital processing the output voltage in eq. (4) is to convert to digital.

With the timing diagram in fig. 5 some statements to the inner processes for distance measurement can be derived.

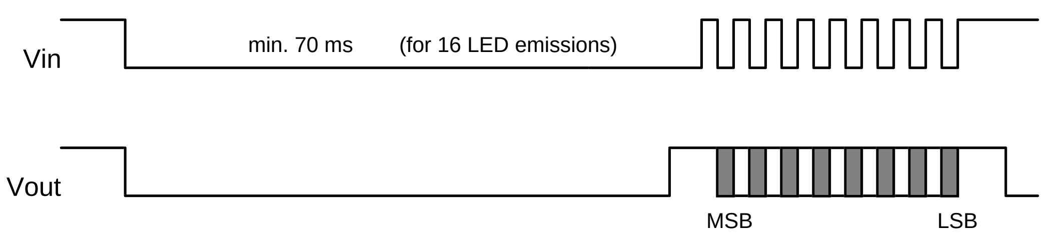

Fig. 5 Timing diagram for measurement and data handling

For controlling the measurement and data handling the two lines Vin and Vout are available. Vin is to drive by an open-drain output. Vout gives an output compatible to CMOS and/or TTL [1].

To start the distance measurement the control line Vin must drop to Lo for a time of 70 msec in minimum. In this time the IR LED transmits 16 pulses in the direction of the measuring object. These 16 measurements allow the calculation of the mean value for reducing possible errors.

After this measuring phase the result can be called from the sensor. The control line Vin has in this phase the function of a synchronous clock input. Starting with the most significant bit (MSB) the eight data bits are available at Vout.

The control program for a connected microcontroller has a very simple structure (Fig. 6).

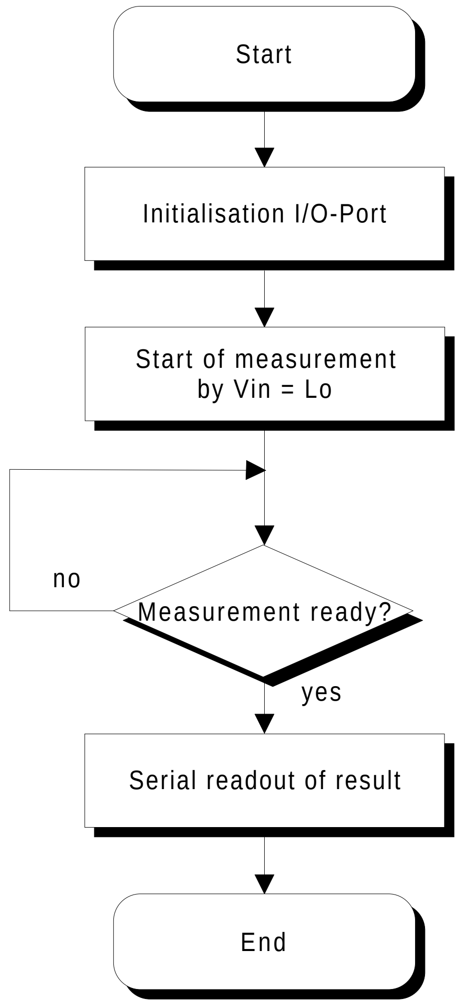

Fig. 6 Structure of control program

Controlling the sensor requires only few resources of a connected microcontroller. Quick results for evaluation (for example) can be achieved by microcontrollers programmable in high-level languages. The BASIC-programmable *BASIC Stamp* (BS1-IC or BS2-IC) from Parallax Inc. is a very good example. Fig. 7 shows a minimum system for distance measurement and display. Additional I/O pins can serve as status outputs.

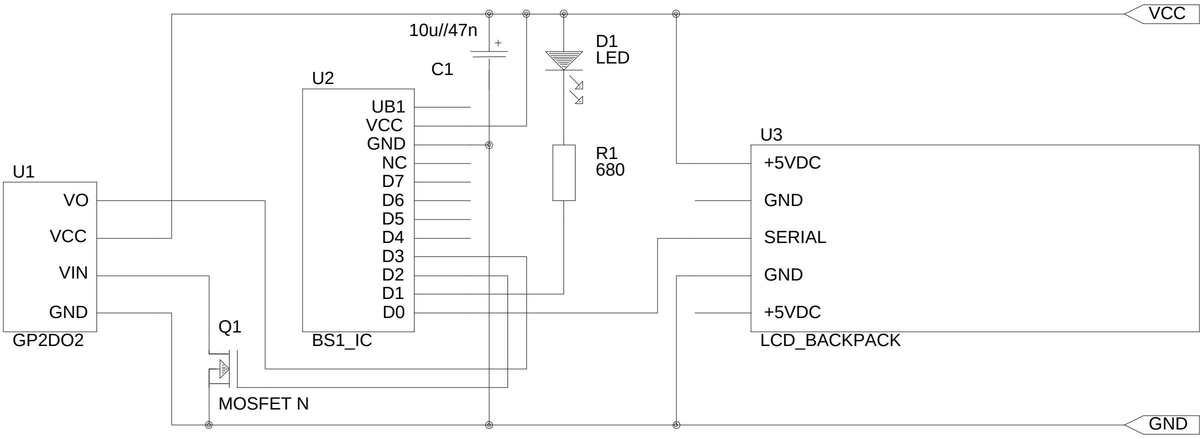

Fig. 7 Minimum system for distance measurement and display

All three units of the whole circuit are powered from the same supply voltage of +5 VDC. I/O line D0 transmits the data to the LCD serial backpack [2]. I/O line D1 drives the LED to visualize the start of measurement. The input Vin of the sensor GP2DO2 is connected to the FET Q1, to fulfill the requirements for an open-drain driver. Over I/O line D3 the serial result of distance measurement will be readout.

The following listing shows the control program for cyclic distance measurements in PBASIC for *BASIC Stamp* I. Changes for *BASIC Stamp II* should be a minimum.

```
' -----[ Title ]-----------------------------------------------------
'
' File......  GP2DO2.BAS
' Purpose...  Test of Distance Measuring Sensor Sharp GP2DO2
' Author....  Claus Kühnel
' Started...  18.03.95
' Updated...

' -----[ Program Description ]---------------------------------------
'
' The distance measuring sensor Sharp GP2DO2 Type 1 measures
' distances between 10 cm and 80 cm.
' The result of 16 measurements is given serial as a count byte.
' The BASIC Stamp controls the starts the measurements, reads the
' result and send it serial to an LCD.

' -----[ Revision History ]------------------------------------------
'
' 18.03.95: Version 1.0

' -----[ Constants ]-------------------------------------------------
'
      symbol LCD    = 0       ' serial output to LCD
      symbol LED    = 1       ' LED control
      symbol Vin    = 2       ' sensor control
      symbol baud   = N2400   ' Baudrate


' -----[ Variables ]-------------------------------------------------
'
      symbol count = b0       ' result of measurement
      symbol i     = b1       ' loop variable
      symbol Vo    = pin3     ' sensor data

' -----[ Initialization ]--------------------------------------------
'
init: low Vin
      high LED
      count = 0
      gosub LCD_clear
```

```
' -----[ Main Code ]---------------------------------------------------
'
start:pulsout LED,20000
      gosub sensor_control
      gosub LCD_print
      pause 1000
      goto start

' -----[ Subroutines ]-------------------------------------------------
'
sensor_control:
      'debug cls
      high Vin
      pause 70
      count = 0
      for i = 0 to 7
          pulsout Vin,10
          count = count * 2 + Vo
          'debug %count
      next i
      low Vin
      'debug count
      return

LCD_clear:
      serout LCD,baud,(254,1,254)
      serout LCD,baud,("Count:")
      return

LCD_print:
      serout LCD,baud,(254,136,254,#count,"  ")
      return
```

Listing Control program GP2DO2.BAS

On the start of each cycle the LED flashes. In the subroutine `sensor_control` happens the start of measurement followed from the serial readout of the result. After the readout the result is stored in the variable `Count.` The subroutine `LCD_print` works like a "print-at" instruction for the LCD and writes the result as decimal number to a defined position. After a waiting period of one second the whole procedure will be repeated.

The following table shows test results for a reflector build from white copy paper.

Distance in cm	10	20	30	40	50	60	70	>80
Counts on display	147	91	71	55	47	44	42	40

Fig. 8 shows a graphical representation of these measuring results.

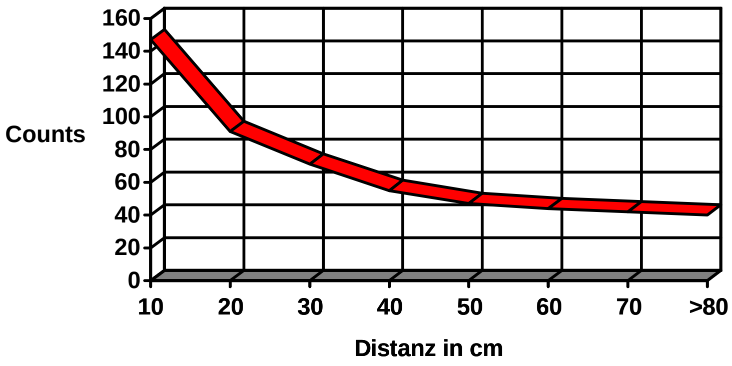

Fig. 8 Characteristic of sensor GP2DO2

An important parameter describing the sensitivity of the sensor is the output distance characteristic ∆Vo. This parameter will be represented by an output change as a result of a distance change from 80 cm to 20 cm. The values of ∆Vo are between 45 and 65 (typical 55). The measured value here was 51 counts and so a little bit smaller as the typical value. The measuring distance range is limited to distances from 10 cm to 80 cm. Distances smaller then 10 cm give angles for the received beam which cannot proceed.

Literature:

[1] Sharp Spec. ED-92024
Distance Measuring Sensor GP2DO2 Type 1
March 12, 1992

[2] Scott Edwards:
LCD Serial Backpack