Poor-man approach to obstacle avoidance

In this tutorial, I want to describe simple IR bumper.
There are many ways to realize object detection. The simplest is just IR LED and phototransistor. Light, emitted from IR LED with wavelength 850-1000 nm, reflects from obstacle and reaches phototransistor. Here, photons generate electrons, and electric current, proportional to the light power will flows through the circuit. Due to current, there is voltage drop on resistor, and if we measure voltage on phototransistor, it will be lesser than battery voltage. Now, we can use comparator or ADC of microcontroller to convert this voltage to valuable information and decide, if there is an obstacle before us. For example if 5 Volts supply is used: 4.5 Volts mean obstacle is far, and 1 Volt means obstacle is close.

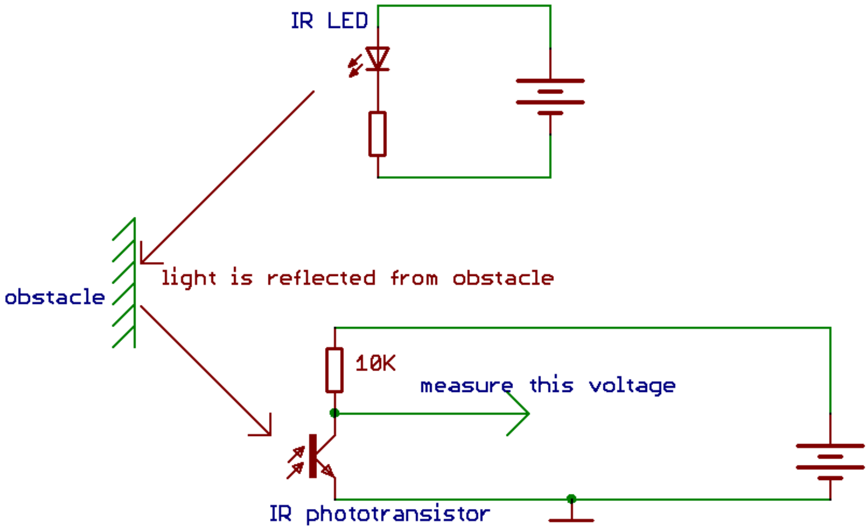


Fig (1). Simplest IR bumper schematic.

But this schematic has big drawbacks. First, the Sun is very powerful source, so this will not work in the sunlight. Also hot bulb in any lamp emits light with high intensity.

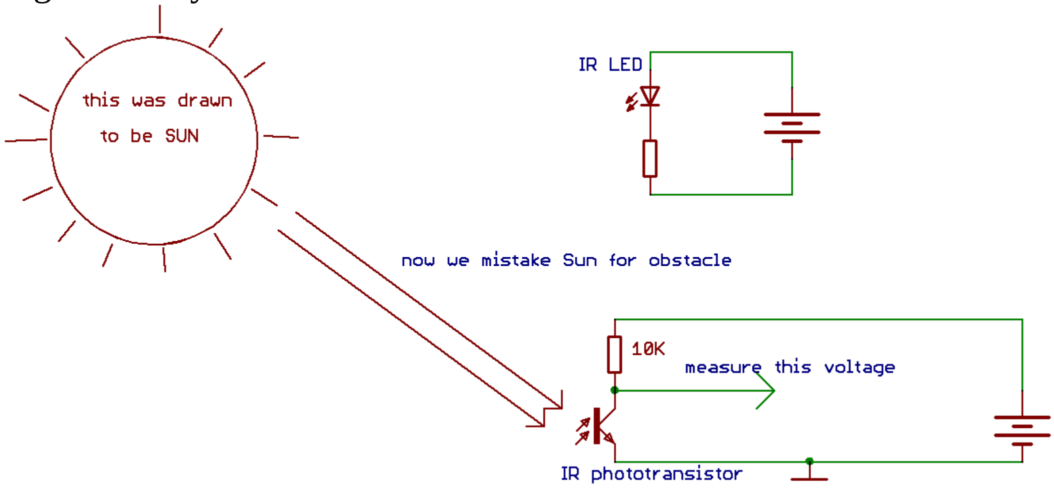


Fig (2). Sunlight impact on simplest IR bumper

There is one way to partially cut-off ambient light with filter and let only LED light to reach phototransistor. The problem is, phototransistor sense in wide wavelength region- from visible wavelength to nearly 1200 nm. The simplest filter it a piece of color photo film, exposed to fluorescent light, and then developed. Film would look black, but it let light with wavelength 820-1050 nm to pass through. However, even with such improvement this schematic lacks of stability.

There is better approach to improve the design. We can modulate IR LED like shown at the fig. 3.

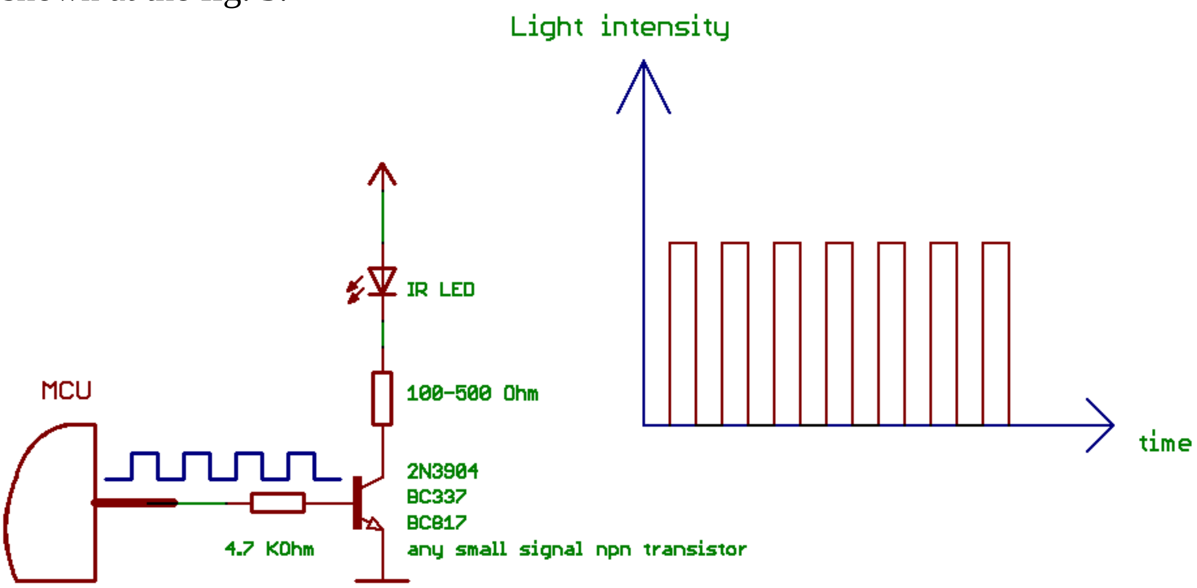
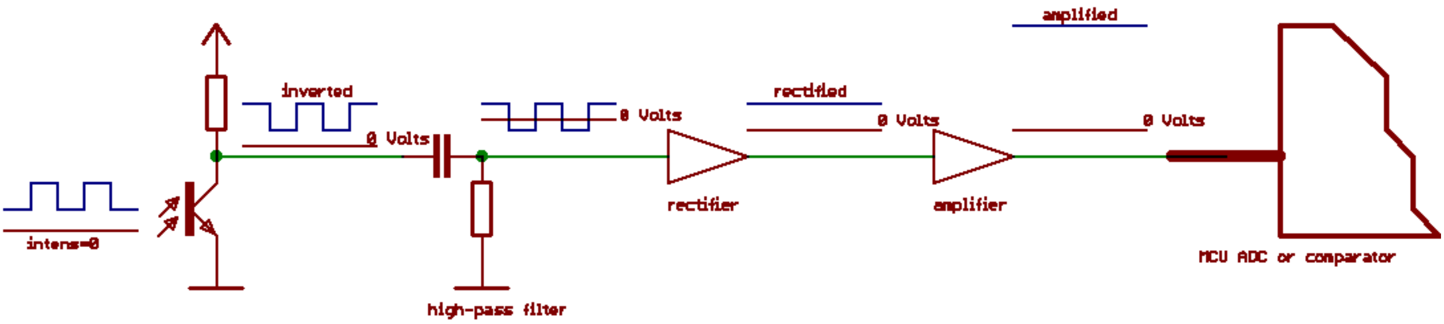


Fig (3). Modulation of light intensity using NPN transistor

Light intensity will be modulated, and voltage at the receiver output will also be modulated. This helps us to detect signal in ambient environment. We now can block DC current with capacitor and get voltage proportional to our modulated signal only, while sunlight constant influence will be blocked. After it, we can amplify and rectify signal to make it suitable for microcontroller recognition.

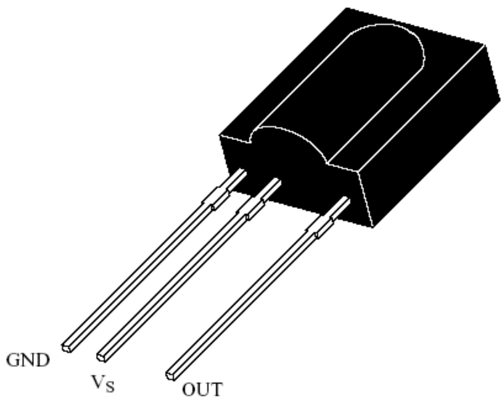


Fig(4). Improved IR bumper schematic

Here, we blocked non-changing ambient signal. However, even now our schematic is not perfect. Ambient light have high intensity, phototransistor and amplifier will saturate. Additional modulated light will not change output voltage, as it will be already as low as possible. These means this receiver has narrow dynamic range. To deal with it, automatic gain control is used. This will make circuit even more complicated and hard to use. Likely to us, all this is already implemented in integrated circuits. They are conventionally used in receivers for IR remote control, but nobody stops us from using them in robotics.
Here, I describe TSOP1736 integrated circuit

Description

The TSOP17.. – series are miniaturized receivers for infrared remote control systems. PIN diode and preamplifier are assembled on lead frame, the epoxy package is designed as IR filter.
The demodulated output signal can directly be decoded by a microprocessor. TSOP17.. is the standard IR remote control receiver series, supporting all major transmission codes.



As you can see, everything is already done for us. It also provides several interesting features:

- Photo detector and preamplifier in one package
- Internal filter for PCM frequency
- Improved shielding against electrical field disturbance
- TTL and CMOS compatibility
- Output active low
- Low power consumption
- High immunity against ambient light
- Continuous data transmission possible (up to 2400 bps)
- Suitable burst length ≥10 cycles/burst

And it’s block diagram:

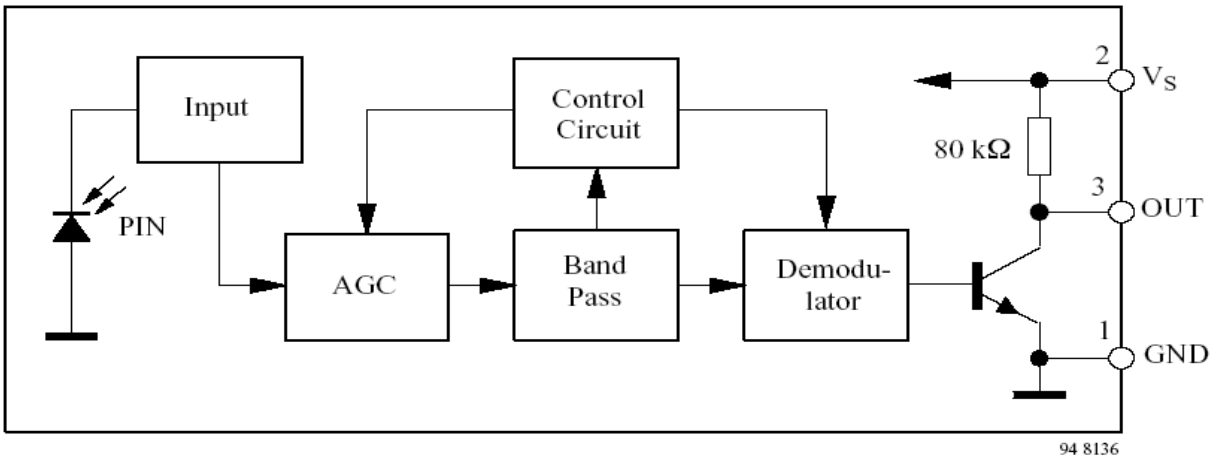


Fig (5). TSOP17.. block diagram

As you can see, this is final schematic with demodulation and AGC.

TSOP17**36** means it is design to sense 36 KHz square wave. There are other frequencies available, but 36 KHz is the most widespread one.
As TSOP sense 36 KHz modulated light, it turns output low. It is because of the output stage, which is transistor switch. It will keep output low for some time and then again rise high- it not just sense 36 KHz but also determine if it constant 36 KHz signal, or a burst of finite number of square waves, i.e. it rejects continuous 36 KHz just like ambient light.

These diagrams explain TSOP behavior:
Reaction on single burst

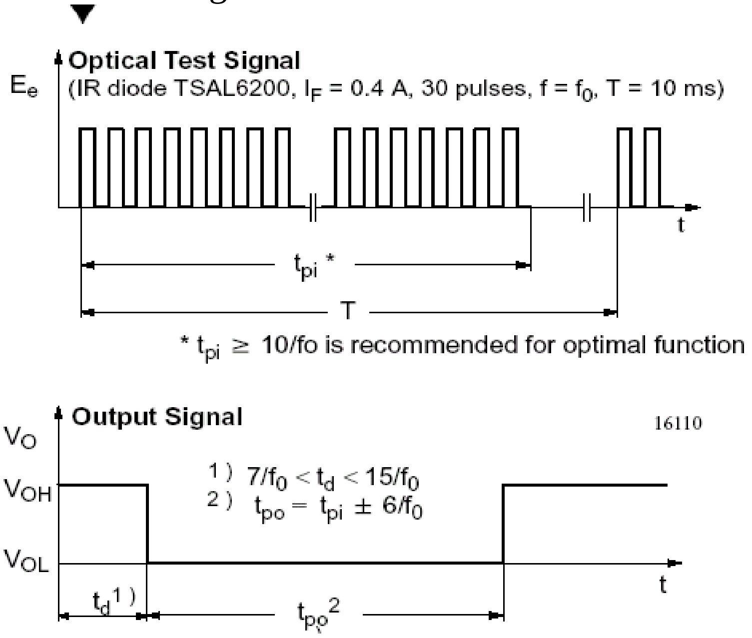


Fig. (6). TSOP reaction on single burst with 36 KHz modulation

Reaction on several bursts one after another

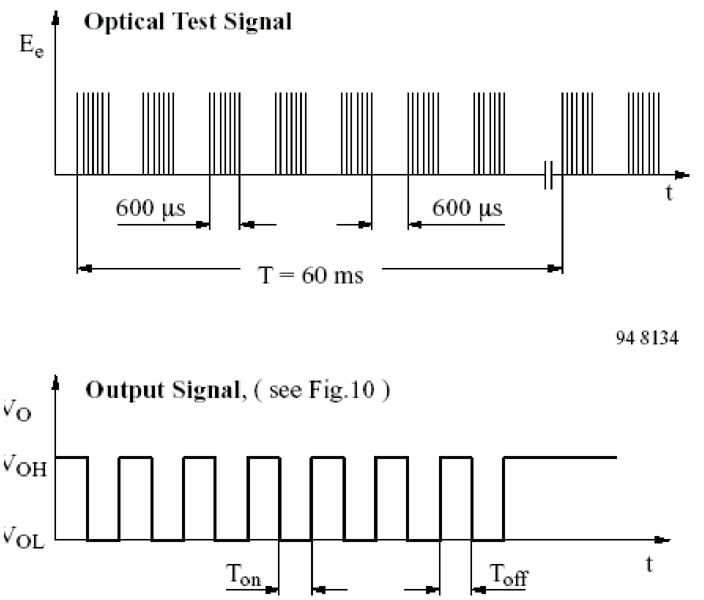


Fig. (7). TSOP reaction on repeating bursts 36 KHz modulated.

And finally, application circuit. From my experience, it is better not to skip resistors and capacitor, because in noisy digital environment false shots are possible. 100 Ohm resistor and 4.7 mkF capacitor form low-pass filter and stop power supply ripple.

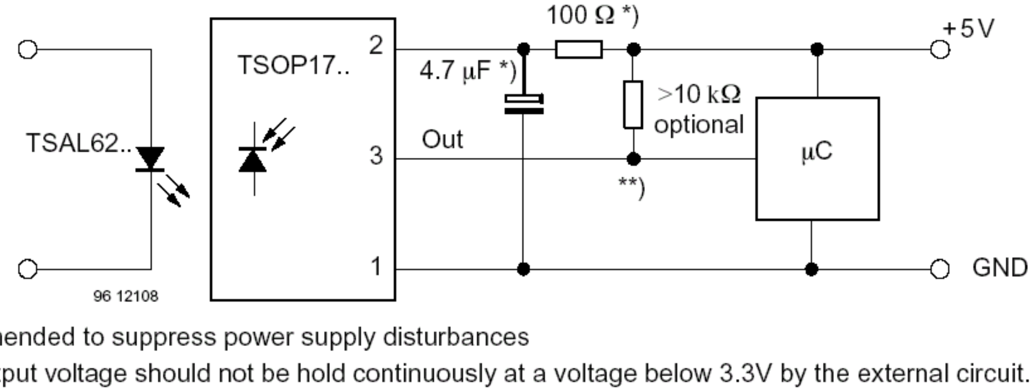


Fig. (7). Application circuit.

TSOP is used with powerful IR LED. TSAL 6200, TSAL5100 and TSAL5200 are widely used and widespread high-intensity LEDs. The best way is use npn transistor to turn LED on or off and shown at fig 3, because it can consume high current (up to 50 mA, depending of the current-limiting resistor value) and MCU pin may not to be able to supply it. Current can be easily calculated as $(V_{sourse}-1.35)/R_{curr.lim}$. I personally use TSAL6200 because of high directivity. - it has well directivity, and when receiver and transmitter are soldered to PCB just near each other (5 millimeters) pointing same direction, diode does not significantly influence TSOP with side radiation. However, additional protection is always welcome.

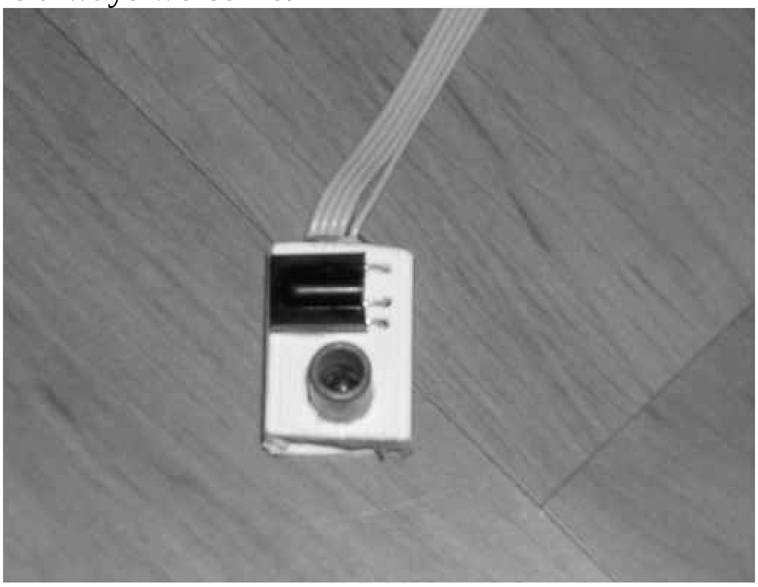


Fig. (8). Assembled bumper.

Cylinder is a lens, focusing invisible IR radiation to the photodiode.
For this IR bumper two MCU pins are required. One pin is used to generate 36 KHz square wave bursts 20-30 pulses each. Another pin is used to monitor output of TSOP. Square wave is generated using timers. Remember, that for 36 KHz square wave, you need to toggle LED twice faster

```
           |1/72K |
           _______            _______
_______|          |________|          |________
           |<    period       >|
             1/36000 sec.
```

Pseudocode, WINAVR, Atmega 8, clock 8 MHz

```
// two IR bumpers are used. IR LEDs are connected to PORTC2 and PORTC3.
// outputs of two TSOPs are connected to PORTC1 and PORTC4.
// indicator visible wavelength LEDs are connected to PORTD0 and PORTD1


// global variables declaration
volatile static unsigned char flag=0b00000000 ; //semaphore variable
volatile  unsigned char  pulses_left=0;    //"right" and "left" determine bumper
volatile  unsigned char  pulses_right=0;  //position in front of robot

// initial setup
DDRC=0b00001100;
DDRD=0b00000011;
// timer 2 is set up to generate 36 KHz square wave, output compare mode.
TCCR2=0b00001010;
OCR2=139;
TIMSK|= (1<<(OCIE2));  // timer 2 output compare interrupt enable
sei();                               // global interrupt enable


// timer 2 interrupt routine
ISR(TIMER2_COMP_vect)
 {PORTC=(PORTC^(flag&0b00001100)); // if bit 2 of flag is set, PORTC2 will
//toggle. Oherwise, it will not. Same with bit 3 and PORTC3.
 pulses_left++;  //increment variables to count pulses
 pulses_right++;
  };
```

```
// main program

 int main (void) {
 while(1){
// first four if sentences are used to realize bursts 25 pulses each with time
//between bursts, equal to lenrgth of 60 pulses on PORTC2 and PORTC3.
 if ((pulses_left>=25)&&((flag&(0b00000100))==0b00000100)) {
        pulses_left=0;  //
        flag=flag&0b11111011;}
        if ((pulses_left>=60)&&((flag|(0b11111011))==0b11111011)) {
        pulses_left=0;
        flag=flag|0b00000100;};
        if ((pulses_right>=25)&&((flag&(0b00001000))==0b00001000)) {
        pulses_right=0;
        flag=flag&0b11110111;}
        if ((pulses_right>=60)&&((flag|(0b11110111))==0b11110111)) {
        pulses_right=0;
        flag=flag|0b00001000;};

if (bit_is_clear(PINC,4))  {PORTD=(PORTD|0b00000001);} // TSOP output
low means it receive modulation. Turn on indicator LED.
 else {PORTD=(PORTD&0b11111110);};  // else turn off.
 if (bit_is_clear(PINC,1))  {PORTD=(PORTD|0b00000010);} else
{PORTD=(PORTD&0b11111101);};
 };
 };
```

As a conclusion, this simple IR bumper can be used as main navigation sensor together with encoders or even without them in simple 1-MCU robot. However, it also can be used together with SHARP rangefinder or Sonar as emergency, or test sensor, or to scan many directions same time. There is no extra information in robotry, only lack of it. It's advantage is it's price- lesser than 1$ per sensor.

Part of pictures were stolen from TSOP17xx datasheet, Vishay Semiconductors, USA.