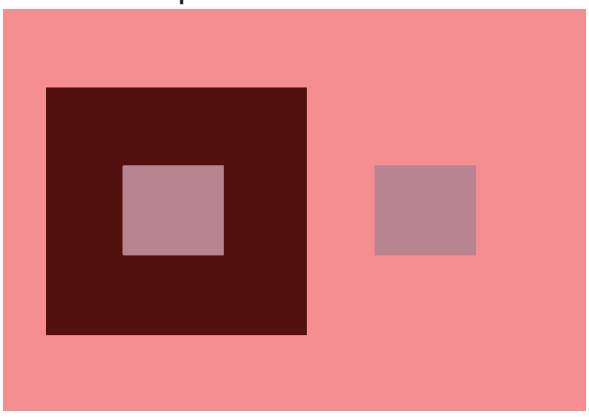
Farba je daná:

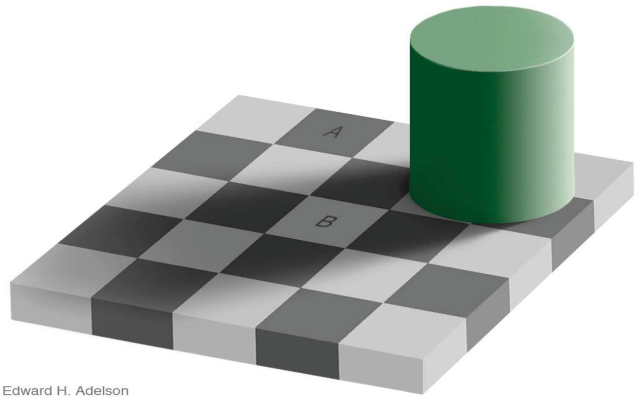
vlastnosťami objektu,

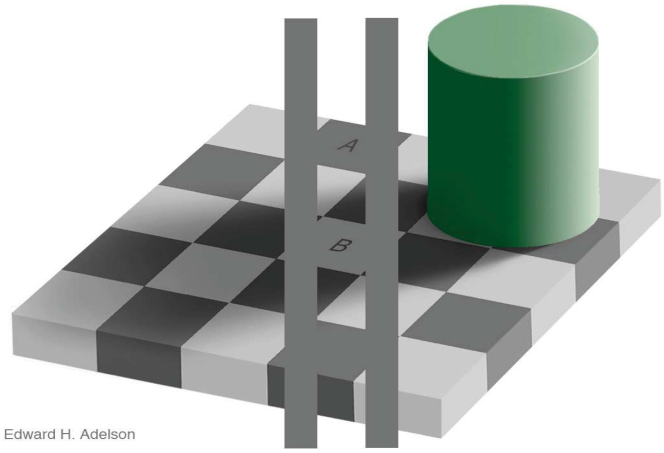
osvetlením objektu,

prostredím a...



...a spracovaním v mozgu!





Edward H. Adelson

Farba

colour, couleur, Farbe, Цвет, szín, barwa, barva

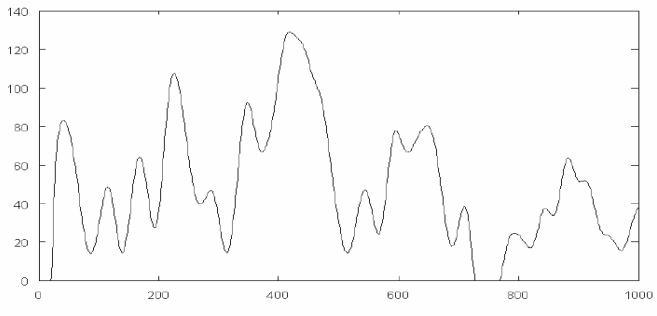
= psychofyziologický vnem sprostredkovaný okom, ktorý ostane ak vylúčime priestorovú, rozmerovú a časovú zložku.

Aj rôzne spektrálne rozloženie môže vyvolať ROVNAKÝ vnem

- **vnem** závisí od
  - farby predmetu (pigmenty, odraz, absorbcia)
  - farby osvetlenia (spektrum)
  - farby prostredia (far. teplota!, filtre)
  - skúsenosti a spracovania v mozgu

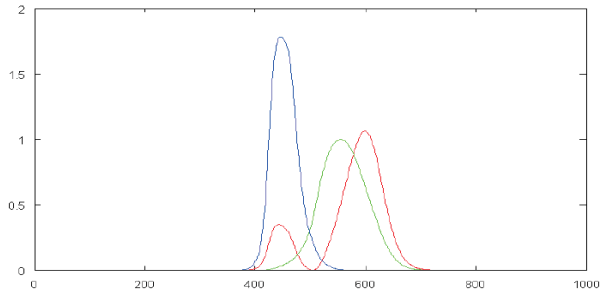
Farba

colour, couleur, Farbe, Цвет, szín, barwa, barva

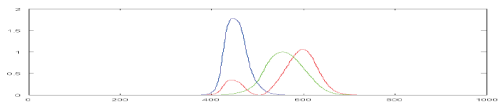


Vnímanie farby

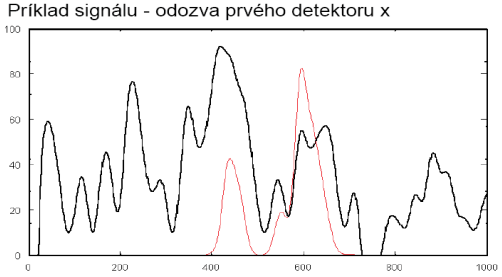
Citlivosť troch detektorov v našom oku



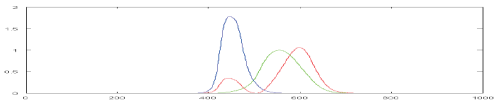
Vnímanie farby



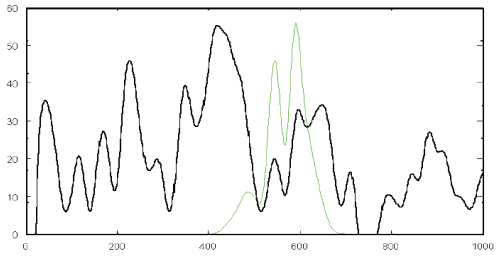
Príklad signálu - odozva prvého detektoru x



Vnímanie farby

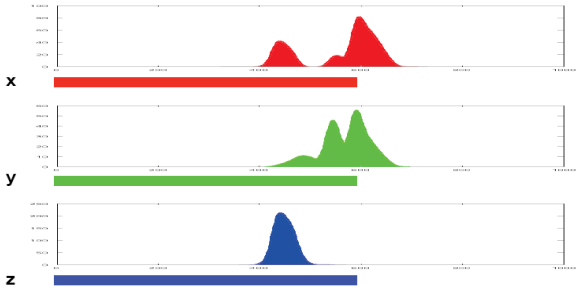


Príklad signálu - odozva druhého detektoru y



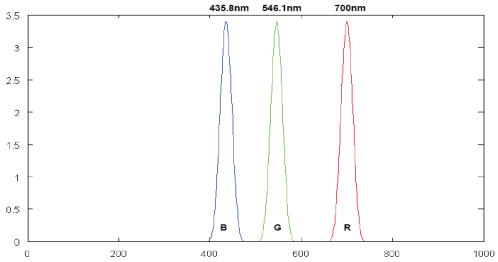
Vnímanie farby

Výsledkom sú len tri čísla, neberie sa ohľad na to ktoré vlnové dĺžky oko práve dráždia



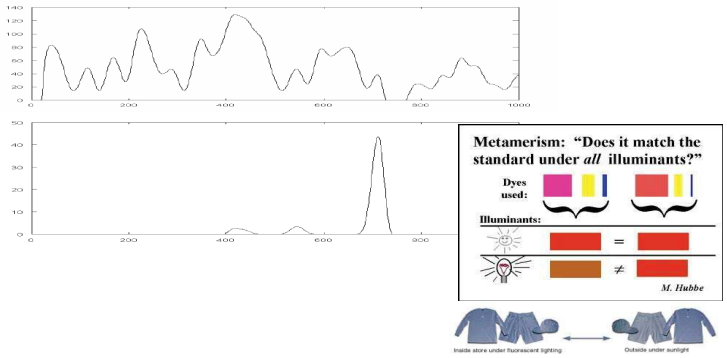
Farba

to využíva monitor počítača, ktorý generuje len tri vlnové dĺžky – červenú, zelenú a modrú – pomocou nich však v mozgu dokáže vyvolať dojem "ľubovoľnej" farby



Vnem
metamerizmus

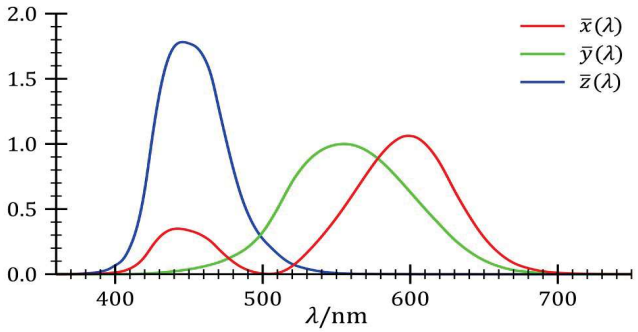
Vskutku tieto dve rôzne distribúcie vyvolajú rovnaký vnem



Vnem

vnem je rovnaký a je to šedá (aj biela by to mohla byť)

Farba



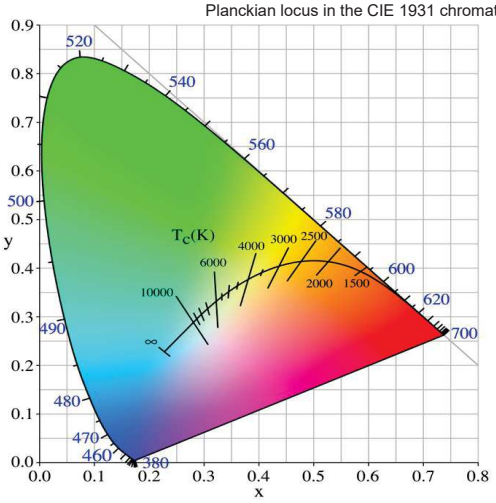
- CIE 1931 Standard Colorimetric Observer functions used to map blackbody spectra to XYZ coordinates

Farebný diagram CIE

- Oko posiela do mozgu vždy tri čísla – x, y, z
- Tento priestor môžeme namapovať do <0,1>x<0,1> (X x Y)

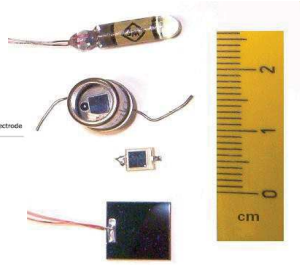
X = x/(x+y+z)
Y = y/(x+y+z)
Z = z/(x+y+z) = 1-(X+Y)

Planckian locus in the CIE 1931 chromaticity diagram

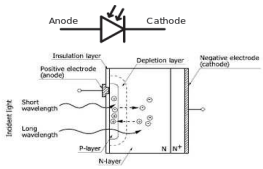


Detektory: fotodióda

photodiode



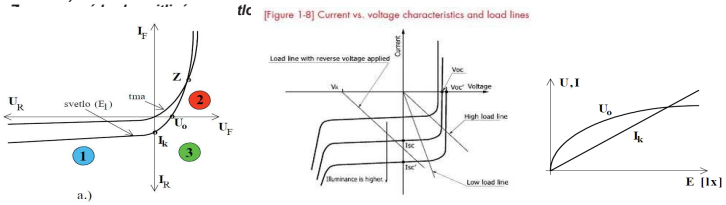
rýchle, málo citlivé



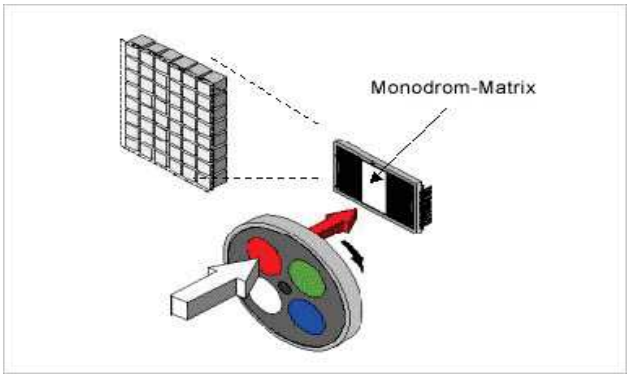
2 - odporový režim v priepustnom smere (rastie E → klesá IR)
3 - hradlový režim (U0 je výst. napätie naprázdno, Ik je výst. prúd nakrátko)

tlc

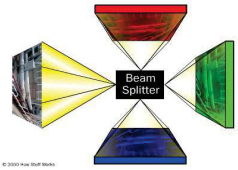
[Figure 1-8] Current vs. voltage characteristics and load lines

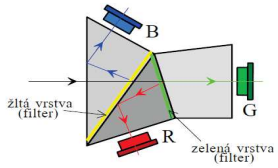


6.1. CCD prvky
snímanie farby – trojité snímanie



6.1. CCD prvky
snímanie farby – tri CCD prvky



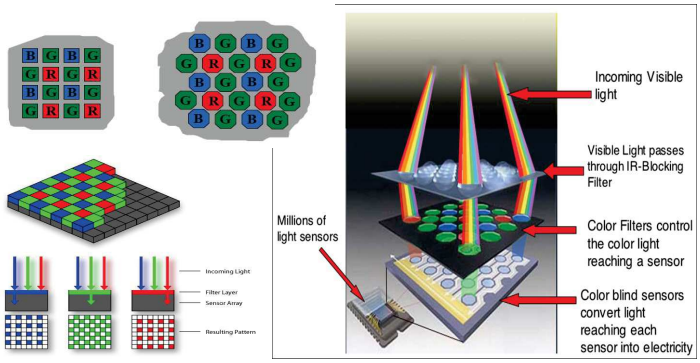


RGB prizma

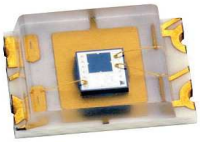
Obr. 48

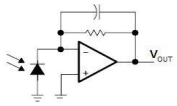
- kvalitné zobrazenie
- náročné na presné nastavenie

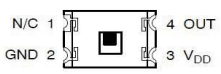
6.1. CCD prvky
snímanie farby – mozaikový filter



ColorPAL

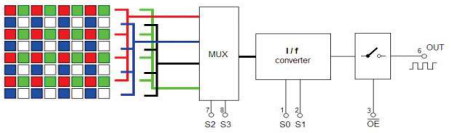


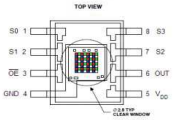




TAOS TSL12T photodiode with integrated Q/U converter.

TCS3200

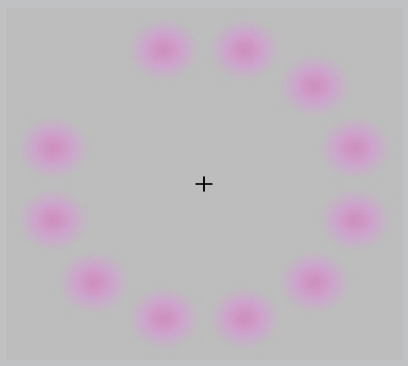




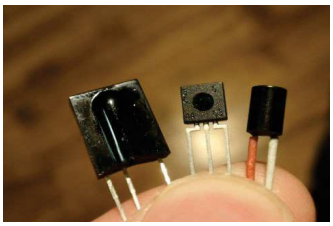
S2	S3	Photodiode
0	0	Red
0	1	Blue
1	0	Clear
1	1	Green

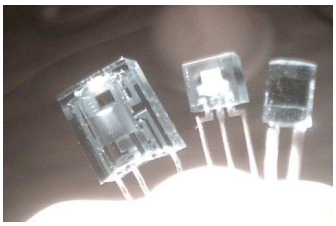
S0	S1	Frequency output
0	0	power down
0	1	2 %
1	0	20 %
1	1	100 %

Akú farbu vidíte?



Detektory: integrované





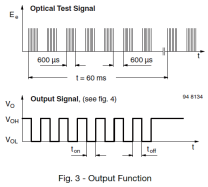
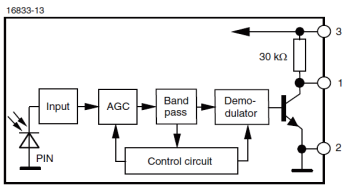


Fig. 3 - Output Function



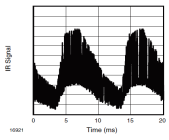
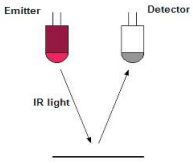
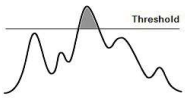


Fig. 14 - IR Disturbance from Fluorescent Lamp



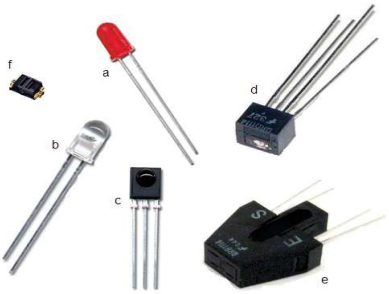
Black = no reflection (0)
= reflection (1)

Output
DIGITAL 0 and 1
ANALOGUE 0-100%



Sources of failures

- Ambient light
- Shadows
- Sun, lamps
- Sources of IR
- Dust, dirt
- Distance!
- Speed



Sensors and detectors:
a) red LED b) Infra red LED c) Infra detector
d) combination emitter + sensor e) larger version
f) miniature SMD version of E+S

Optical line sensor principle

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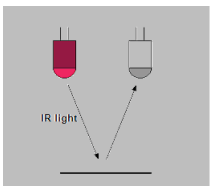
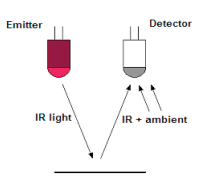
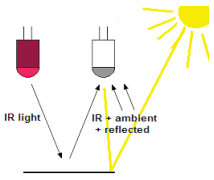


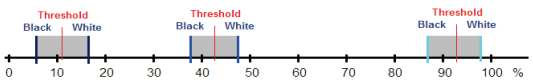




Sensor output

Sensor detector measures not only the reflected IR light, but also the amount of the ambient light

- **Shields!**
- **Calibrate!**



Sensor calibration

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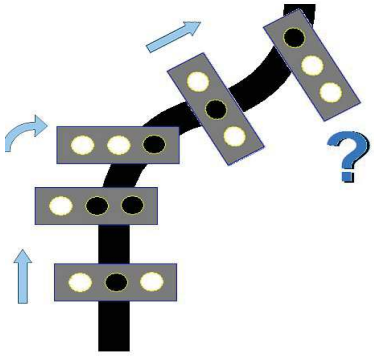

Three sensors

Sensor	Action
010 (line)	go.forward
011 (right)	turn.right
001 (right)	sharp.right
100 (left)	sharp.left
110 (left)	turn.left
111	**???**
000	**???**
101	**???**

Algorithms

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More sensors?

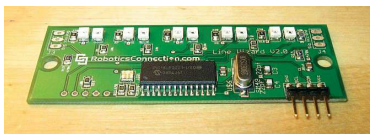
Adds more reliability

Different width of line

Proportional control

controller output is proportional to the error, which is the difference between the desired and actual positions.

Different shapes enable to determine sharp turns in advance.



Algorithms

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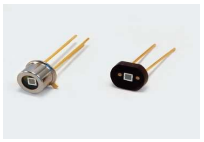
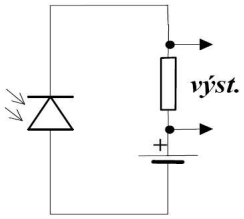
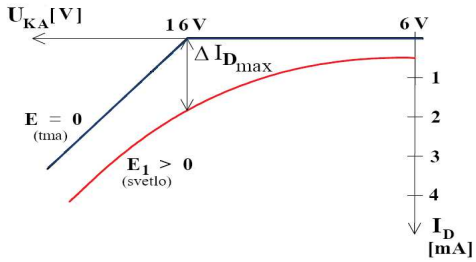
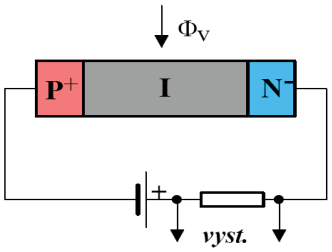
lavínová fotodióda
avalanche photodiode





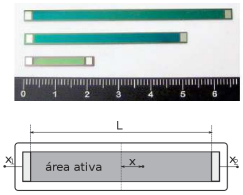


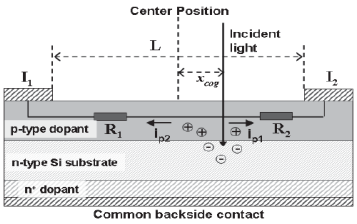
PIN fotodióda
avalanche photodiode



I – intrinzická časť
– prijíma fotóny, izolácia
- vysoké U → rýchlosť 10^{-12} – 10^{-15} s

PSD prvky
position sensitive device

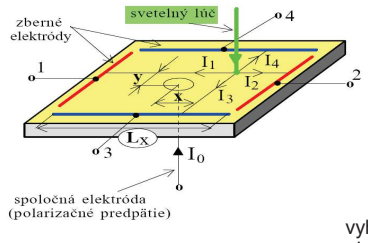


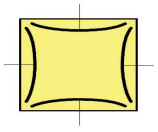


$$x = \frac{L}{2}\frac{I_2 - I_1}{I_2 + I_1}$$

- informácia o POLOHE, nie o intenzite
- celkový prúd (cez spoločnú el.) I_0 = 1μA!
- rozlíšenie 12μm, chyba ±0,9%
- obvykle laser, modulovaný – lepšie SNR

PSD prvky
position sensitive device





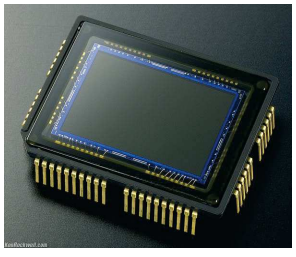
$$x = \frac{L_x}{2}\frac{I_2 - I_1}{I_2 + I_1} \qquad y = \frac{L_x}{2}\frac{I_4 - I_3}{I_4 + I_3}$$

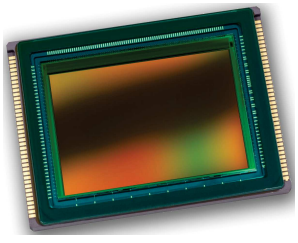
vyhodnotenie 4 prúdov voči zbernej elektróde

x a y sú vzdialenosti od stredu

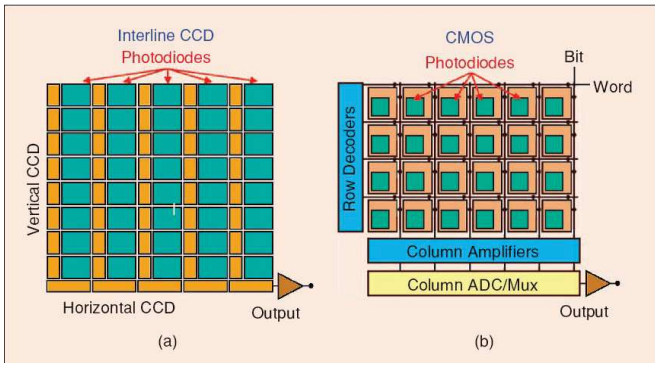
6. Optické snímače

CCD a CMOS

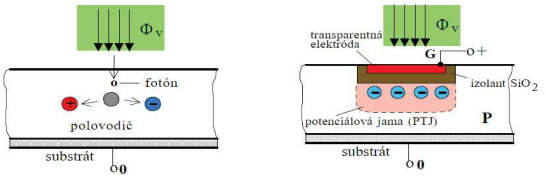




6. Optické snímače



6.1. CCD prvky
charge coupled device

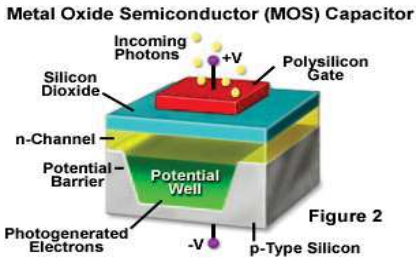


Obr. 42.

Uchovávame tzv. menšinové náboje, teda v P polovodiči elektróny. Tieto môžu vznikať :

- tepelnou generáciou - parazitný jav (šum)
- injekciou svetlom - vlastný snímací efekt
- injekciou z blízkeho PN prechodu - odovzdanie výstupného signálu

6.1. CCD prvky
základná CCD bunka

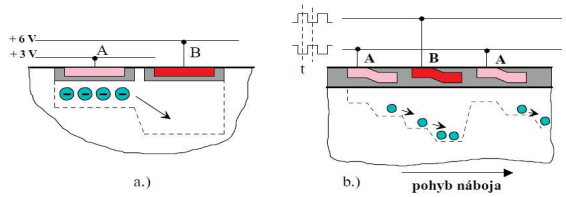


Charge-Coupled Device

- Invented at Bell Labs in 1970
- 2009 Nobel Prize in Physics
- Widely used in TV, medical, astronomy cameras
- Array of light sensitive MOS capacitors (pixels)
- Incoming light generates electrons which are captured in a potential well
- Electrodes, or gates, move the charge

From http://learn.hamamatsu.com/articles/quantumefficiency.html
Image from http://www.microscopyu.com/articles/digitalimaging/ccdintro.html

6.1. CCD prvky
prenos náboja



Obr. 43.

Vyšší potenciál vytvorí hlbšiu PTJ, nosiče do nej prepadávajú.
Tvarované elektródy - tvarovaná PTJ
Elektródy A a B - výstupný register

6.1. CCD prvky

Množstvo nosičov závisí od intenzity osvetlenia E a od času t:

expozícia (osvit) e : *(e býva označené tiež H)*

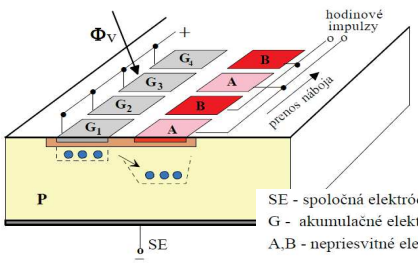
$$e = E \cdot t \quad [lx.s\ ;\ lx;\ s;] \qquad (6 - 2)$$

Poznámka: Doba existencie náboja v PTJ je asi 100 ms ÷ 10 s. (vyrovnanie tepelnou generáciou). Dlhé časy - problém, už cca 5 ÷ 10 s vyžadujú chladenie prvkov, napr. polovodičové, resp.softwérové potlačenie. (následné zosnímanie bez obrazu a odčítanie)

6.1. CCD prvky
riadkový CCD senzor

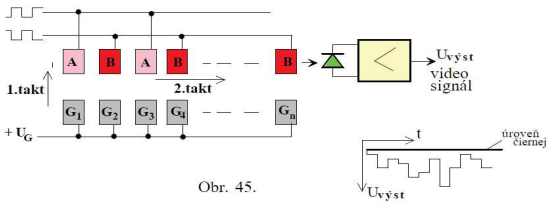
Riadkový CCD senzor

1. Svetelný tok $\Phi_v \rightarrow$ náboj pod G_1, G_2, atď.
2. Po dobe expozície presun náboja pod A,B
3. Fázovo posunuté impulzy na A,B - vysúvanie nábojov



SE - spoločná elektróda (–)
G - akumulačné elektródy, predstavujú pixely a
A,B - nepriesvitné elektródy registra

6.1. CCD prvky
riadkový CCD senzor



Obr. 45.

Video signál:
- poloha bodu - čas od začiatku prenosu
- osvetlenie bodu - amplitúda.

Počet pixelov - 128 (termovízia), po 6 - 10 tis.(profi scannery...)
Rozmery : od 6 x 6 µm do 17 x 8 µm.

6.1. CCD prvky
riadkový CCD senzor

Princíp elektronickej uzávierky

Doba snímania (pre 1728 pixelov) → hodinové impulzy :
10 kHz → doba snímania = 86 ms (1/12 [s])
10 MHz → doba snímania = 86 µs (1/12000 [s])
Optimálne cca 10 ms (1/100 [s]), čomu zodpovedá 86 kHz.

Výhody: netreba mechanickú uzávierku - cena
Nevýhody: pomalé vysúvanie - akumulujú svetlo aj počas vysúvania (náchylnejšie na smearing, blooming)
rýchle vysúvanie - nekvalitné (rýchle) odčítanie náboja

T/2 spôsobí posun o jedno miesto, resp. T vysunie polovicu pixelov (párne - nepárne)

E = 10 lx dáva 0,2 V na výstupe.
Citlivosť na svetlo: ASA (DIN) a je 100 ÷ 3200 ASA (21 ÷ 36 DIN).
Poznámka: Horná hranica je už 6000 - 12000 ASA, diskutabilná je kvalita (malé snímače)

Rozlíšenie úrovní šedej 8 - 32 bitov → 256 - 4,295. 10^9 úrovní. (štand. 24 bit)

6.1. CCD prvky
riadkový CCD senzor

Použitie riadkových CCD :
- nepohyblivé obrazy (scannery...) - snímanie po riadkoch
- snímanie polohy (ako PSD)
- iné, napr. zaostrovacie systémy - vyhodnotenie kontrastu (krížový senzor, hrany)

Ako zobrazovacie systémy potrebujú vysokokvalitnú optiku s vysokým rozlíšením pre malé ohniskové vzdialenosti (3 - 8 mm)

6.1. CCD prvky
Front or Back Illuminated

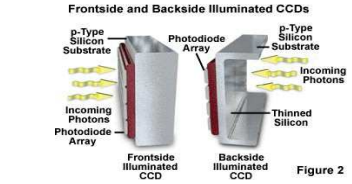
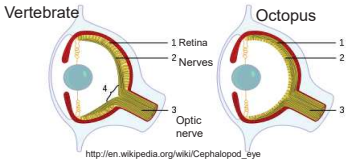


Figure 2



From http://learn.hamamatsu.com/articles/quantumefficiency.html

- Traditional, front-illuminated have **wiring in front** of photosensitive region
  - This blocks some light, reducing QE
- Back-illuminated CCDs:
  - Back side of the CCD is etched to 10-15 microns
  - More fragile and costly, but higher QE

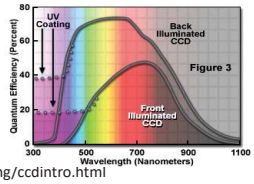
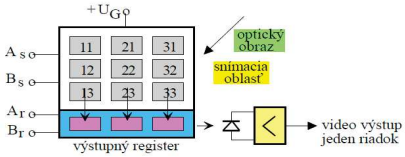


Figure 3

Image from http://www.microscopyu.com/articles/digitalimaging/ccdintro.html

6.1. CCD prvky
maticový CCD senzor:Full frame



Obr. 46.

Činnosť :
- obraz sa premietne na snímaciu časť → pod elektródami náboj
- hodinové impulzy na A_s , A_r (1 fáza), a B_s , B_r (2 fáza) → jeden riadok do výstupného registra.
- hodinové impulzy na A_r , B_r → obsah registra po pixeloch do výstupu.

- častejšie pre väčší formát (24 x 36 mm) - pridaný "bočný register"
- pri vysúvaní by nemal reagovať na svetlo - zakrytie (mechanic. uzávierka)
- lacnejší

Bucket brigade analogy for read out

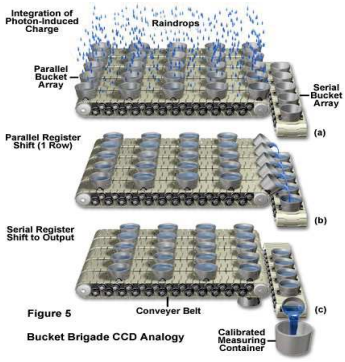
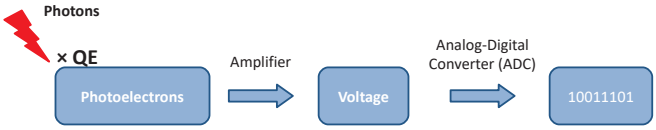


Figure 5
Bucket Brigade CCD Analogy

- Rain accumulates in buckets
- Rows of buckets shifted to readout row
- Readout row shifted bucket-by-bucket to measuring device
- Unless rain stops, last bucket to be read out will have much more water than the first

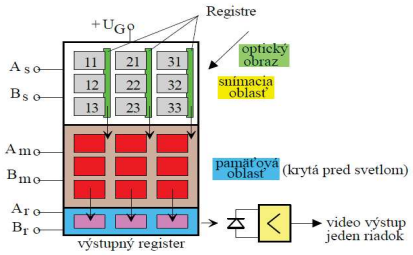
6.1. CCD prvky
vyčítanie obsahu...



Bit Depth	Number of gray levels
8	28 = **256**
10	210 = **1024**
12	212 = **4096**
14	214 = **16384**
16	216 = **65536**

6.1. CCD prvky
maticový CCD senzor: frame transfer

- pridaná pamäť (rovnaká)
- pridaný zvislý register k stĺpcom v sn. časti (Al elektródy, krytý pred svetlom)
- úbytok plochy (citlivosť) – nad pixelom mikrošošovka (HAD)



Obr. 47.

6.1. CCD prvky
snímanie farby

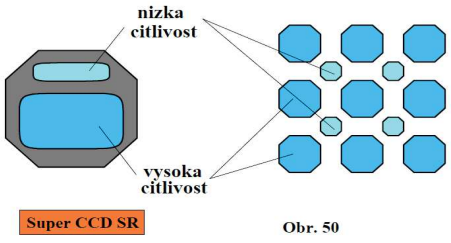
RGB systém
tri základné farby:
R (Red - červená), G (Green - zelená),B (Blue – modrá)

Poznámka: Jedna sa o aditivne miesanie farieb - svetiel.

Možnosti:
- postupne tri expozície cez tri filtre
- tri identické obrazy - tri senzory
- jeden "trojitý" maticový senzor + tzv. mozaikový filter.
- systém FOVEON

6.1. CCD prvky
snímanie farby – dynamický rozsah

Zväčšenie dynamického rozsahu.



Obr. 50

CMOS Detectors

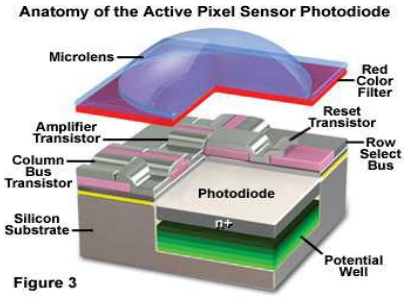


Figure 3

Complementary Metal Oxide Semiconductor

- Transistors in **each pixel** convert charge to voltage
- More can be done within a pixel meaning **frame read out can be faster**
- Fabricated much like microprocessors and RAM so are **cheaper to make**
- Used in webcams, phone cameras since they use **less power**

Active Pixel Image Sensor

- 3-4 transistors per pixel.
- Fast, higher SNR, but
- Larger pixel, lower fill factor.
- Lower voltage and lower power.

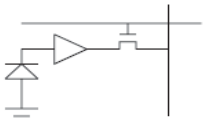
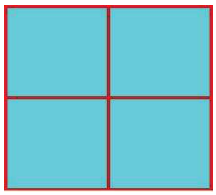


Image from http://www.olympusmicro.com/primer/digitalimaging/cmosimagesensors.html

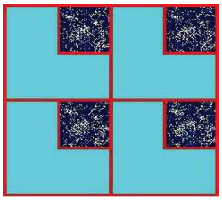
What is a Pixel?

- The smallest discrete component of an image or picture on a CRT screen is known as a pixel.
- Each pixel is a sample of an original image, where more samples typically provide more-accurate representations of the original.



What is Fill Factor?

- Fill factor refers to the percentage of a photo site that is sensitive to light.
- If circuits cover 25% of each photo site, the sensor is said to have a fill factor of 75%. The higher the fill factor, the more sensitive the sensor.



CMOS Detectors

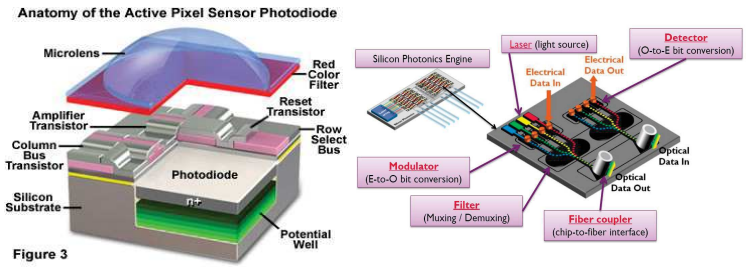
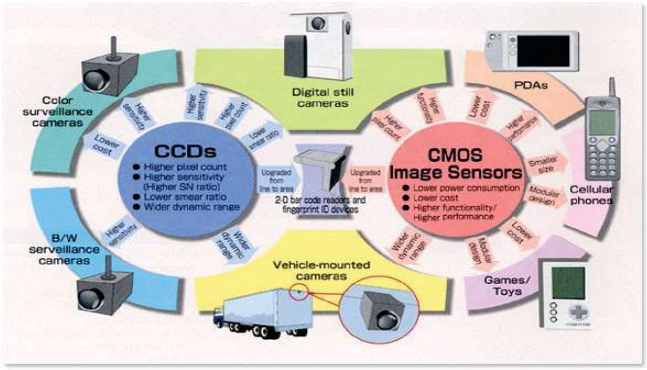


Image from http://www.olympusmicro.com/primer/digitalimaging/cmosimagesensors.html

6.1. CCD vs. CMOS



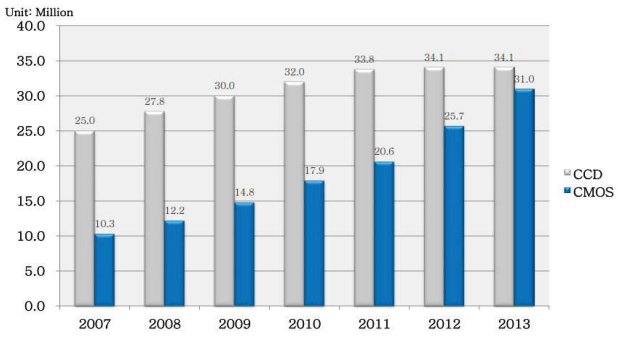
6.1. CCD vs. CMOS

- Create high-quality, low-noise images.
- Greater sensitivity and fidelity
- 100 times more power
- Require specialized assembly lines
- Older and more developed technology

- More susceptible to noise
- Light sensitivity is lower
- Consume little power
- Easy to Manufacture
- Cheaper

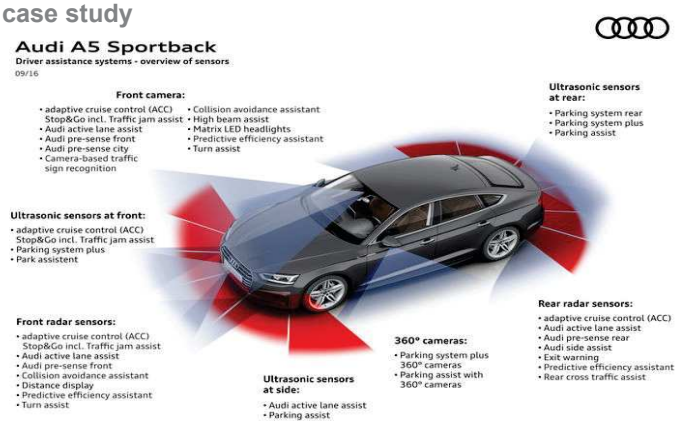
Picture quality, sensitivity and cost vs. Cost and battery life.

6.1. CCD vs. CMOS

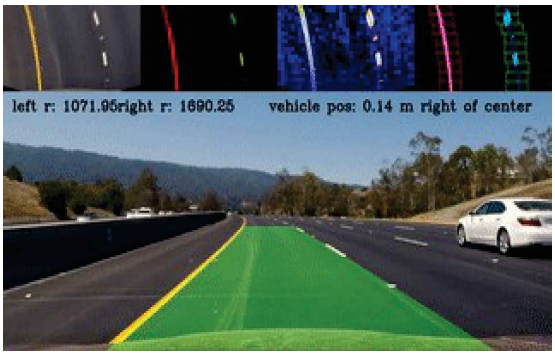


6.1. Kamery v automobiloch

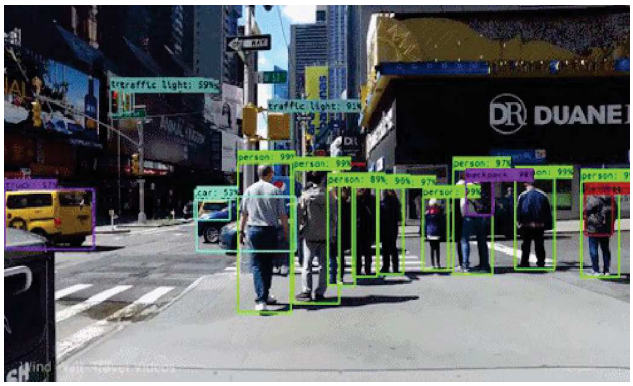
case study



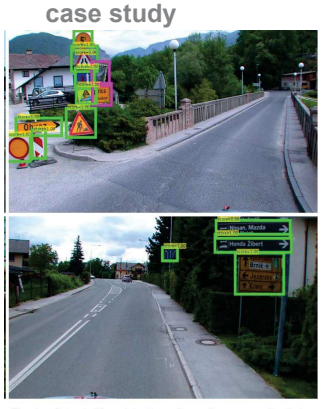
6.1. Kamery v automobiloch
case study

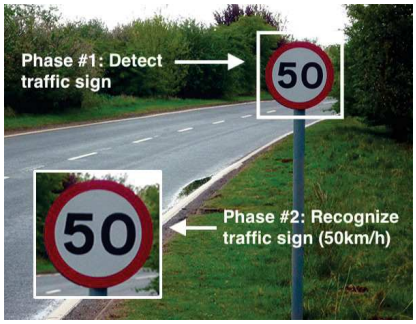


6.1. Kamery v automobiloch
case study



6.1. Kamery v automobiloch
case study

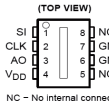


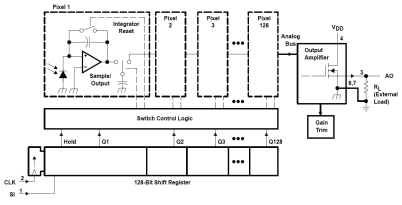


6.1. Kamery v automobiloch
case study

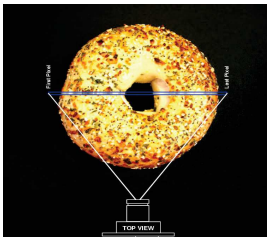
Príklady

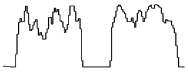
Riadkový CCD snímač
TAOS TSL 1401 CL



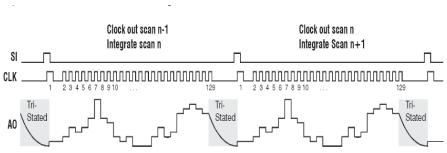


Riadkový CCD snímač
TAOS TSL 1401 CL

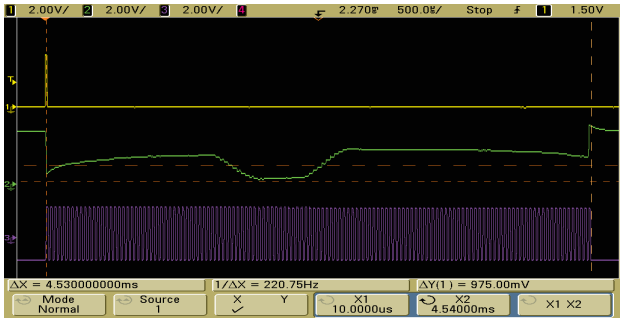




- 1 x 128 pixels
- 0 - 5 V output for each pixel
- 1 pixel / 1 clock pulse



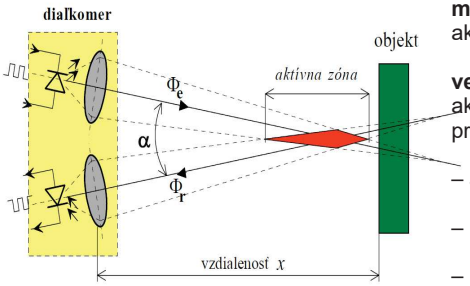
Riadkový CCD snímač
TAOS TSL 1401 CL



Optical distance sensors

6.2. Optické princípy
Optické diaľkomery

Optical rangefinder



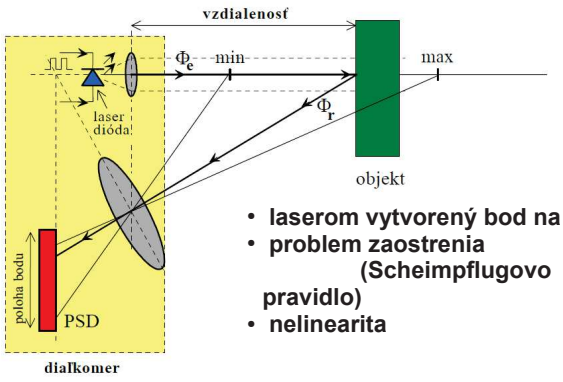
malé α – dlhá úzka aktívna zóna (väčšie x)

veľké α – krátka široká aktívna zóna → proximitné snímače

– amplitúda úmerná vzdialenosti
– poruchové vplyvy
presnosť malá
– modulovaný svetelný tok
– optika (šošovky, zrkadlá)

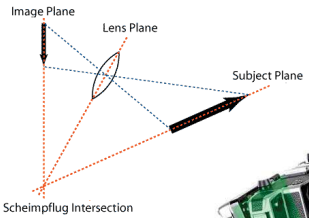
Reflexný optický diaľkomer

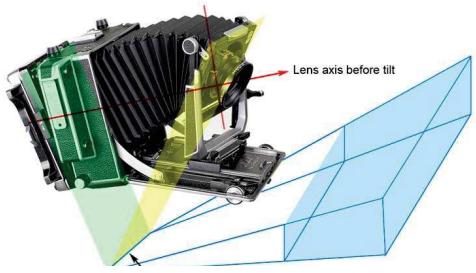
6.2. Optické princípy
Triangulačný diaľkomer



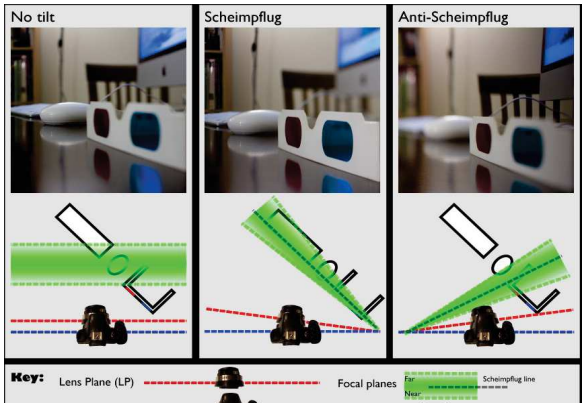
- **laserom vytvorený bod na telese**
- **problem zaostrenia (Scheimpflugovo pravidlo)**
- **nelinearita**

6.2. Optické princípy – Triangulačný diaľkomer
Scheimpflugovo pravidlo





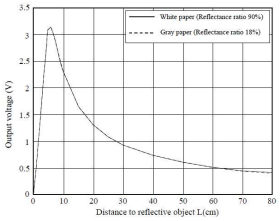
6.2. Optické princípy – Triangulačný diaľkomer
Scheimpflugovo pravidlo



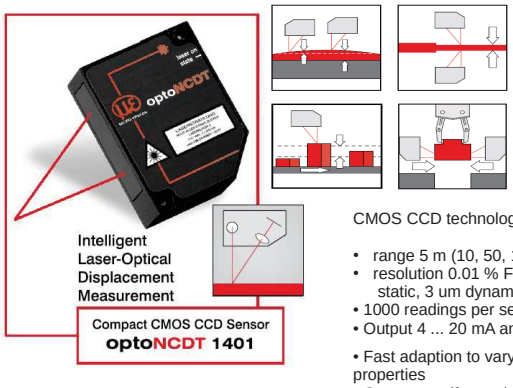
6.2. Optické princípy
Triangulačný diaľkomer

SHARP GP2Y0A21YK0F

GP2Y0A21YK0F Distance Measuring Sensor Unit
Measuring distance: 10 to 80 cm
Analog output type



6.2. Optické princípy
Triangulačný diaľkomer



CMOS CCD technology

- range 5 m (10, 50, 100, 200 mm)
- resolution 0.01 % FSO (1 um static, 3 um dynamic 1kHz)
- 1000 readings per second
- Output 4 ... 20 mA and RS232
- Fast adaption to varying surface properties
- Compact self-contained sensor