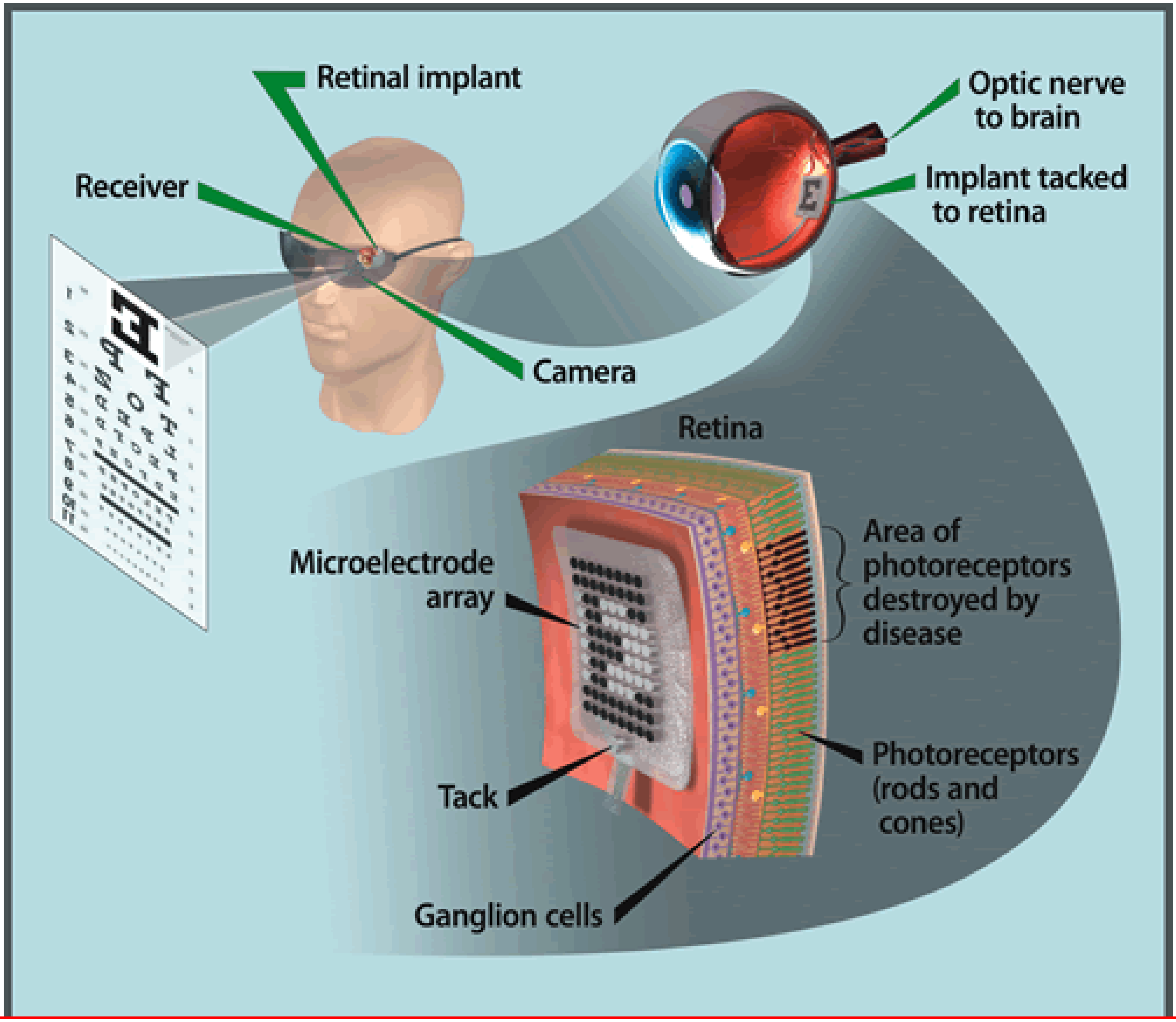


Electronics for artificial vision

References:

"Multiple-Unit Artificial Retina....”; Wentai Liu, et al. (available onf the course Web site)

"An Implantable Neuro-stimulator....”; Mark Clements, et al. (available onf the course Web site)

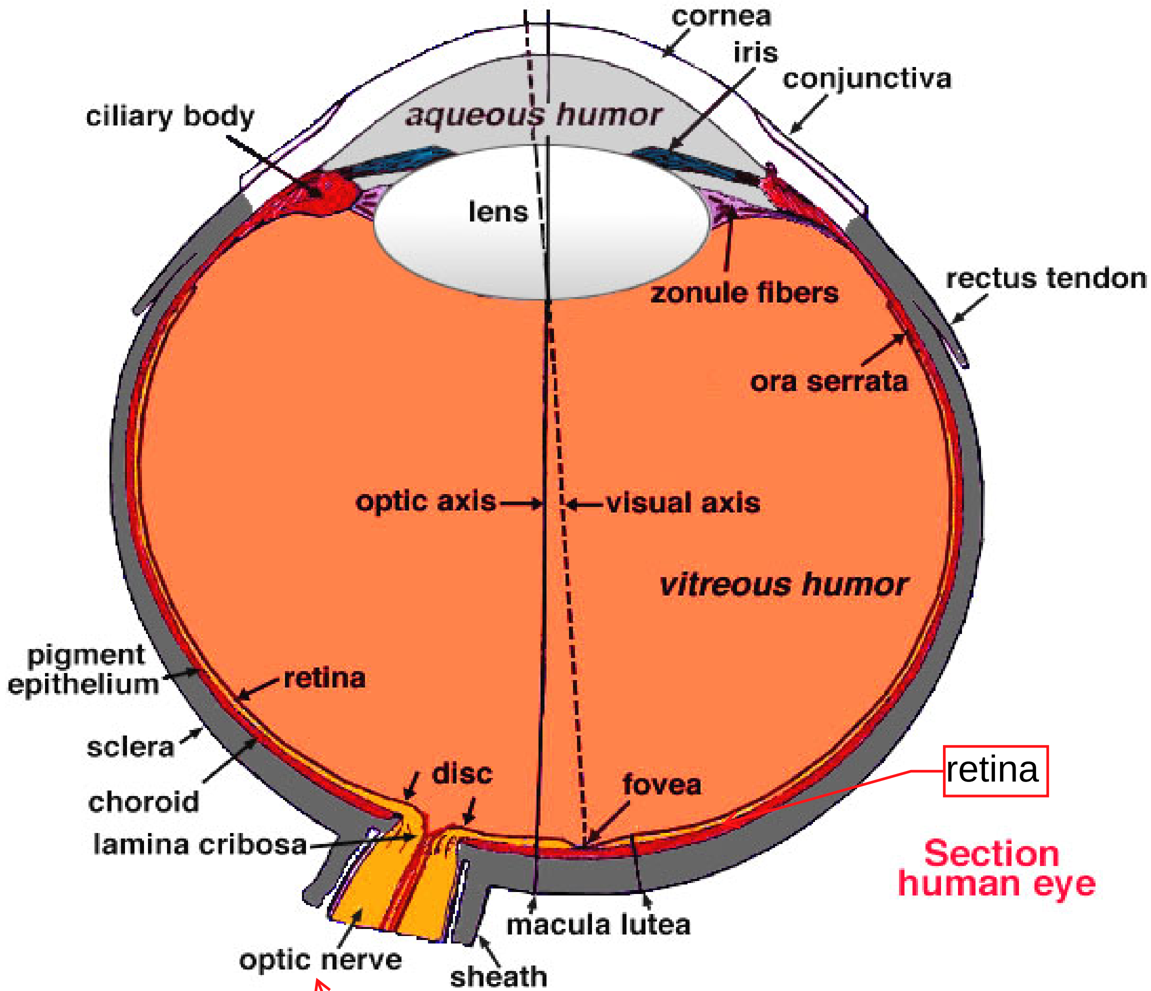
Commercial systems:

- Alpha IMS
- ARGUS II

Chips implantend in the retina. It simulates the AP taken by optical nerve. Different type of disesase that make you blind; restore at least sensation of obj moving/populating. IN this: the image is acquired by a camera, placed on a pair of glassese, then it's processed by a DSP, transformed in a format compatible of stimulation of tissues. Then data are transmitted thorug the eye with internal unit (maybe rf, or optical link, no direct connection). Then image reconstructed, image sent to array of microelectrodes and they provide the stimula. Two papers.

Eye anatomy

image flipped

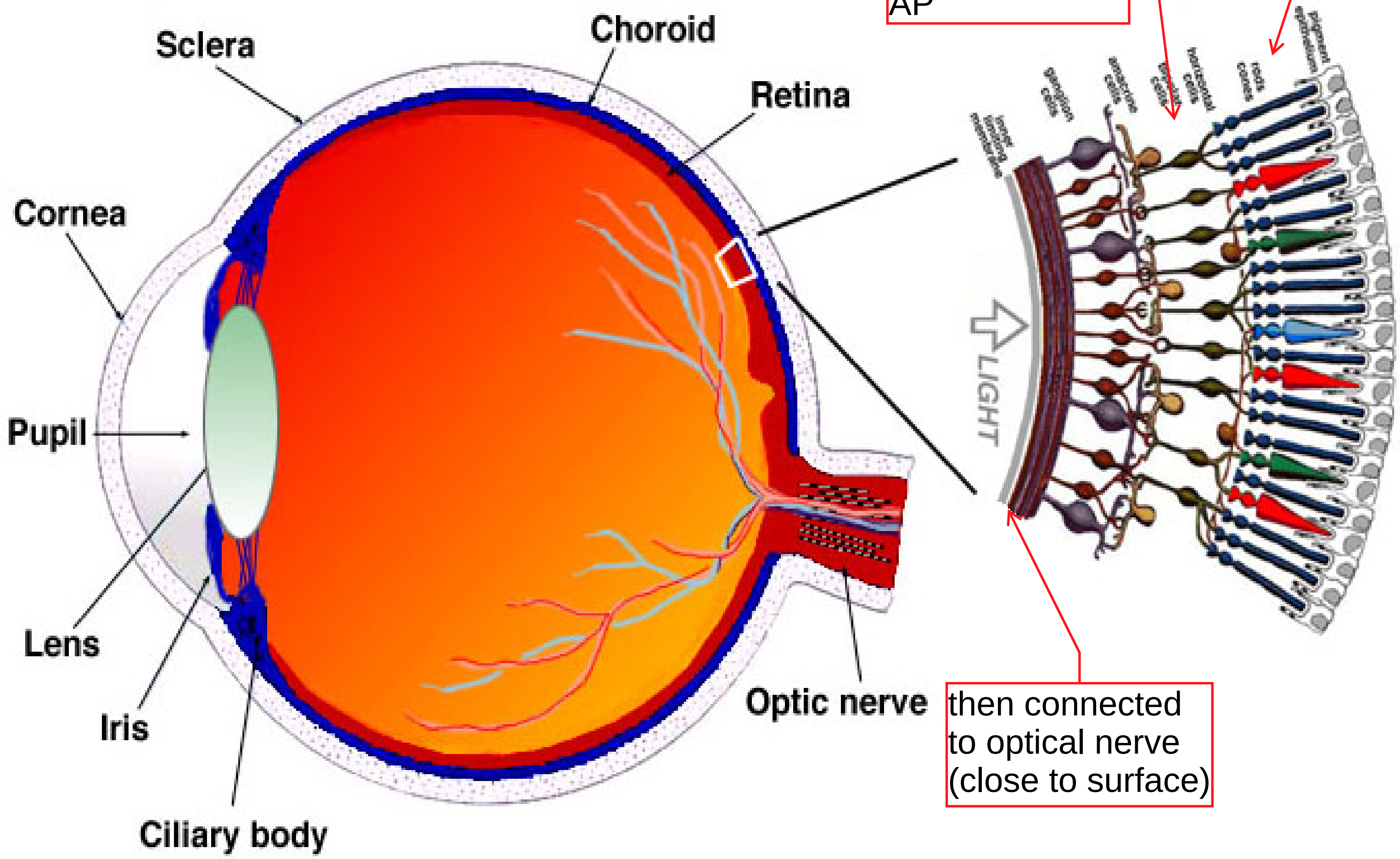


then connected
to the brain

The retina

Layer of photoreceptors: converts optical photons in electrical

distributing the AP

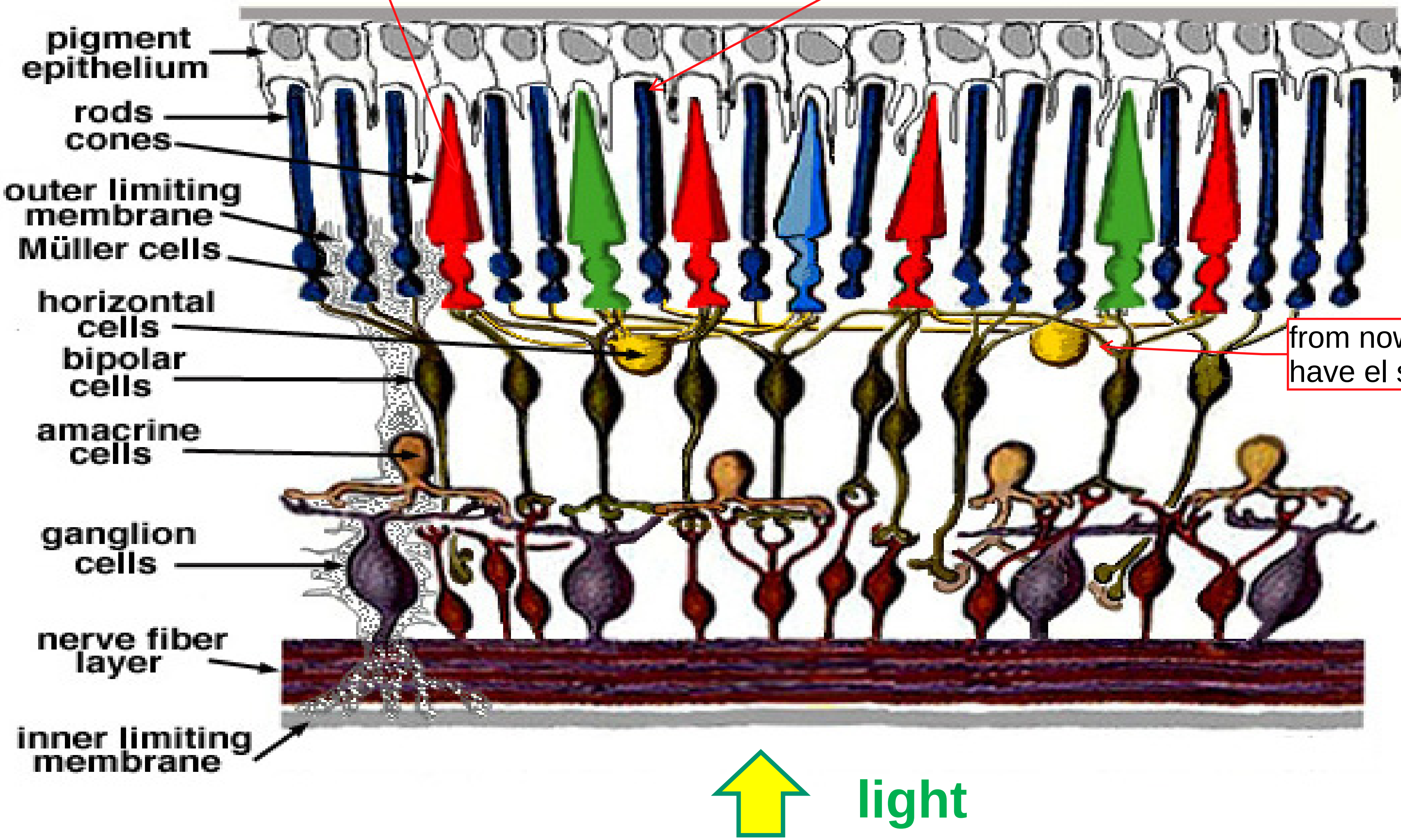


then connected to optical nerve (close to surface)

The photoreceptors ARE NOT IN THE FRONT, they are embedded in the internal layer of the retina. Important for prosthesis, the type depends on which layer it has to be implanted.

cones => p.r. for 'daylight' conversion, large dyn range, provide color sens

rods: low dynamic range of intensity of light. act in darkness. Limited color percp.



from now you have el signal

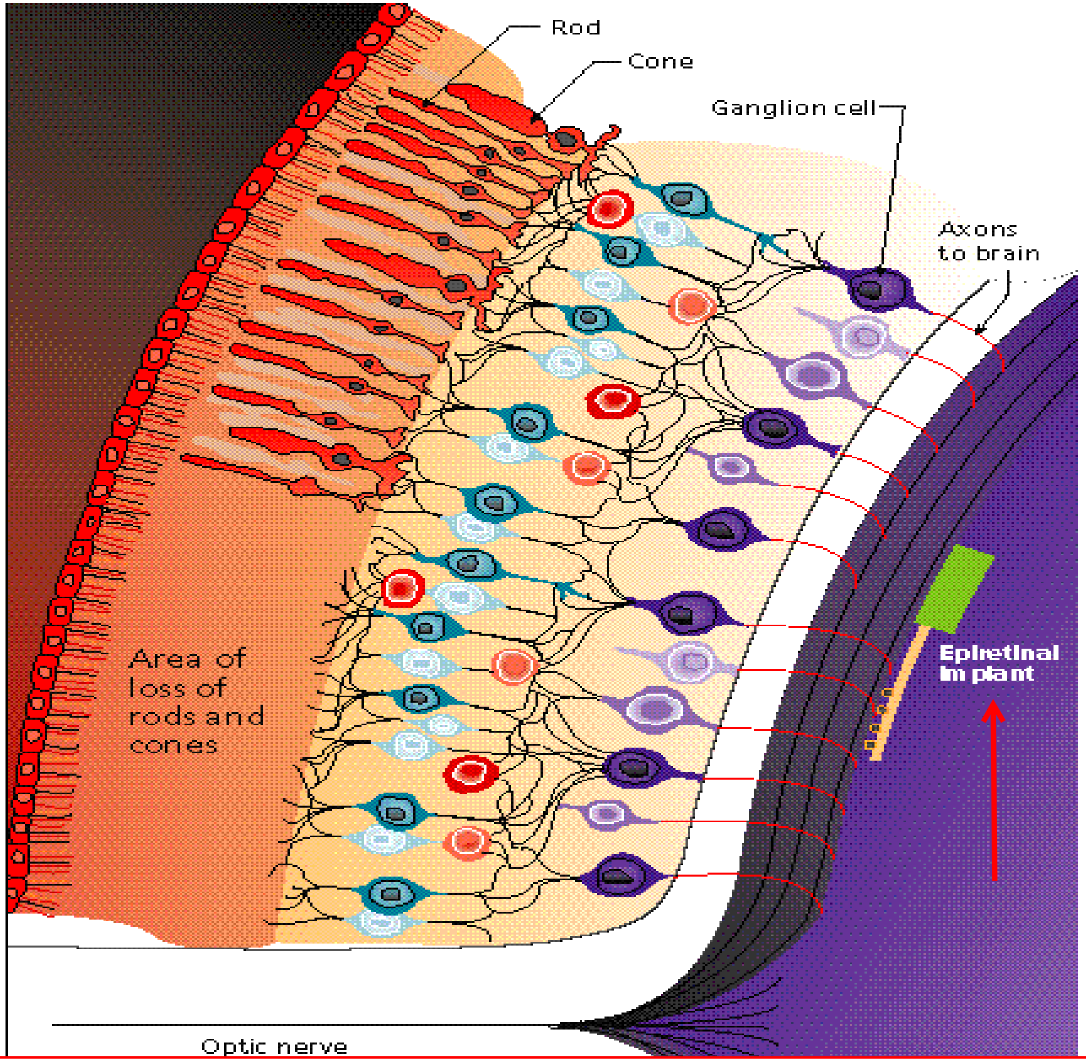
All these layers perfor a kind of processing. Emulating the vision with a prosthesis is not just the "pure" conversion of photons->el signal, but also how to emulate the internal analog processing of the signal by these layers.

Epiretinal prosthesis

- Electrical stimulation on the layer of ganglion cells
- Limits: loss of signal pre-elaboration carried out by the previous cellular layers
- Need of an external image processing device (DSP)
- Examples of realized prototypes:

  MIT-Harvard device,

  MARC project

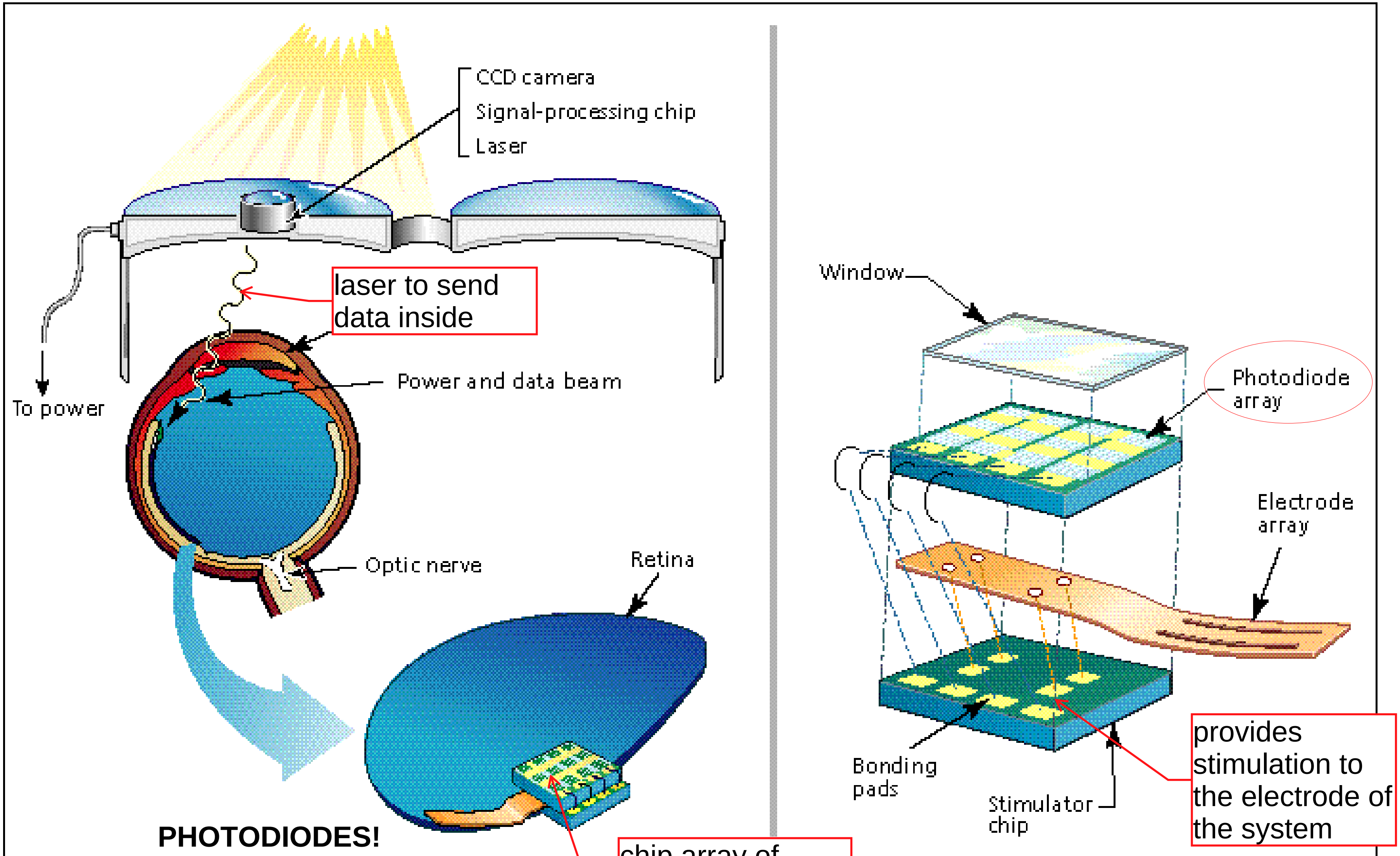


Type of prosthesis. **EPIRETINAL**=> implantend on the surface of the retina.They are in contact where the el. signal are supposed to arrive already (already after the processing). They are popular b/c they are implantend in the more easily accessable layer of retina. Surgery difficult, but this is the easiest. LIMIT: LOST PRE-ELAB made " spontaenous" by the retina. We have to supply an "high level" information.

- A CCD camera receives the image
- The external video processor processes the image
- The signal is sent to the internal chip by either radiofrequency transmission (MARC) or optical transmission (MIT) optical trans doesnt need a physical link (aka "laser")
- The stimulator chip generates the current pulses and sends them to the microelectrodes

MIT

fast

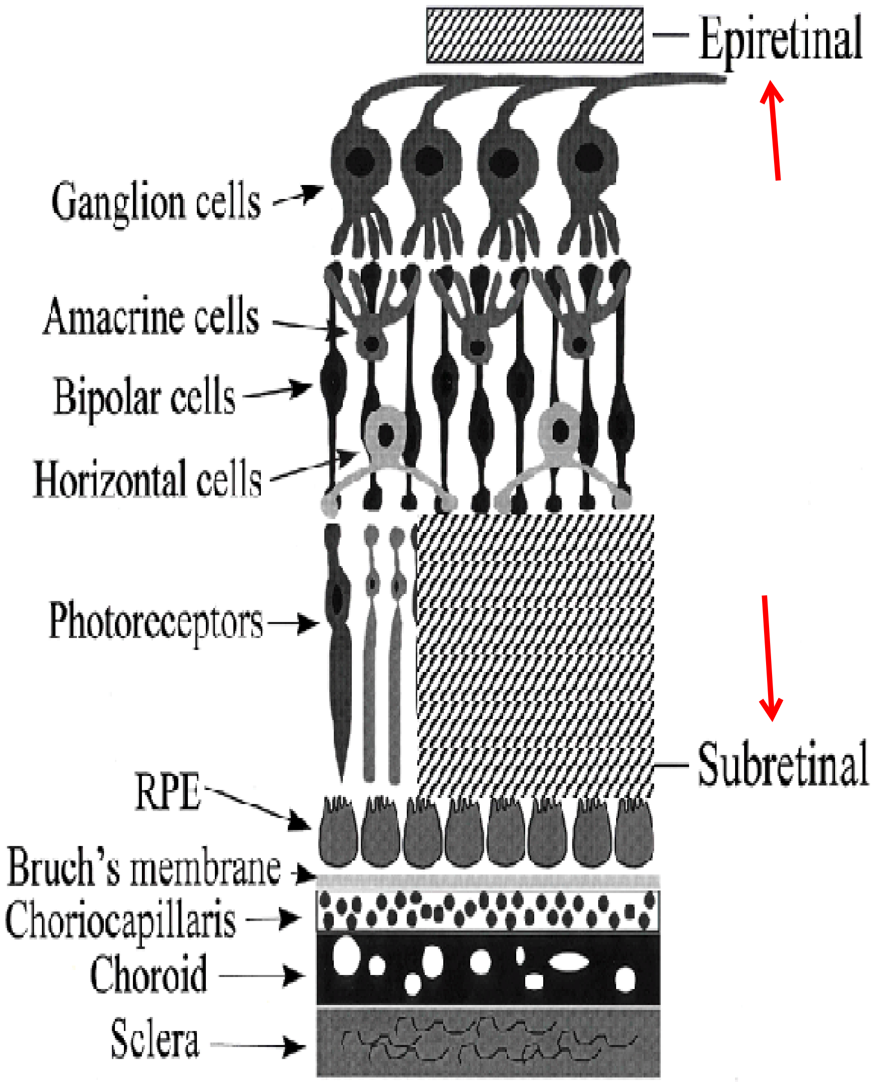


chip array of **photo diodes that convers laser=>electrical**

Subretinal prosthesis

fast

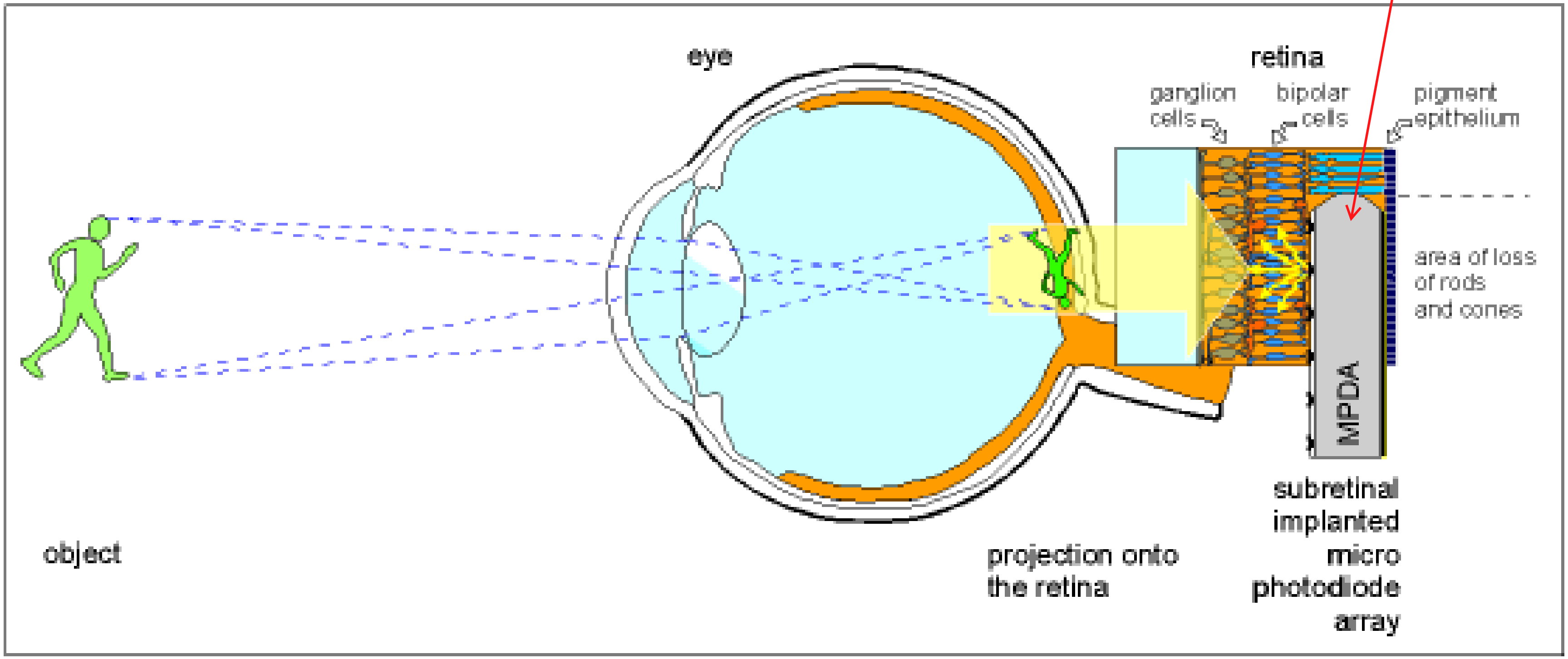
- The prosthesis substitutes the layer of degenerated photoreceptors
- The pre-processing role of the following cellular layers is maintained.
- The prosthesis is made out of an internal unit (relative design simplicity)
- A photodiodes array converts the light into electrical pulses which are transmitted to the healthy cells through gold microelectrodes.



Other classes.. subretinal: more difficult to implant. Idea to **substitute photoreceptors**. They have to be implanted in the p.r. area. This way we exploit the remaining connectivity (intrinsic processing of the eye). PROBLEM: layer in depth, **more invasive**.

fast

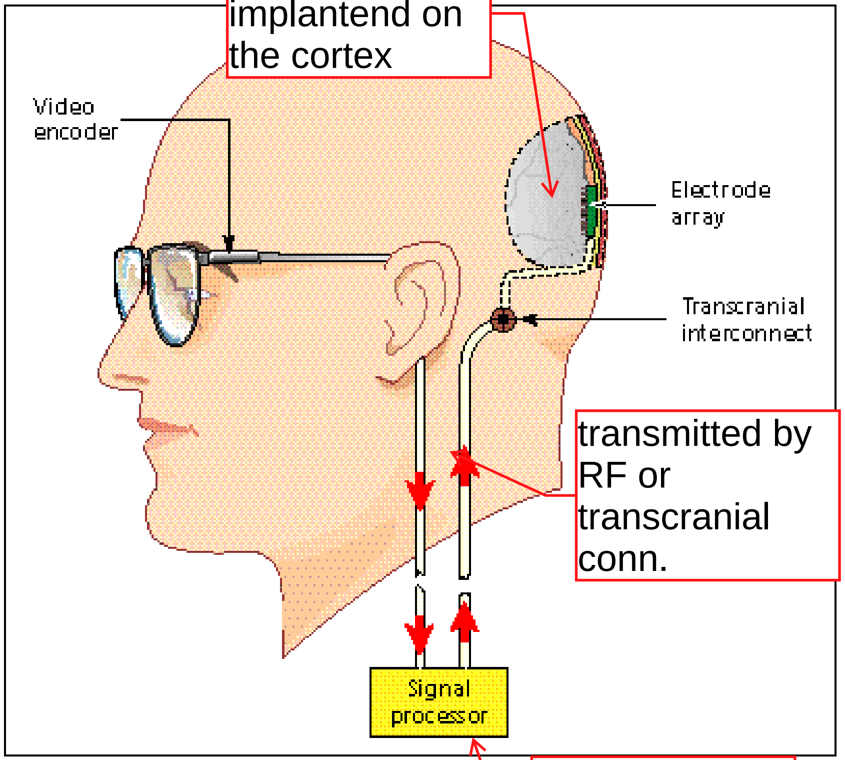
photodiodes that converts light in electrical signal



fast

Cortical prosthesis

- The prosthesis is made by an array of microelectrodes which is placed in contact with the cortical tissue
- A portable computer processes the images and correct them for the non-linearity of the retina-cortex map
- The external unit is connected to the internal one by a RF system or by a transcranial interconnection
- These prosthesis offer the advantage to cope with pathologies which affect the optic nerve (glaucoma)



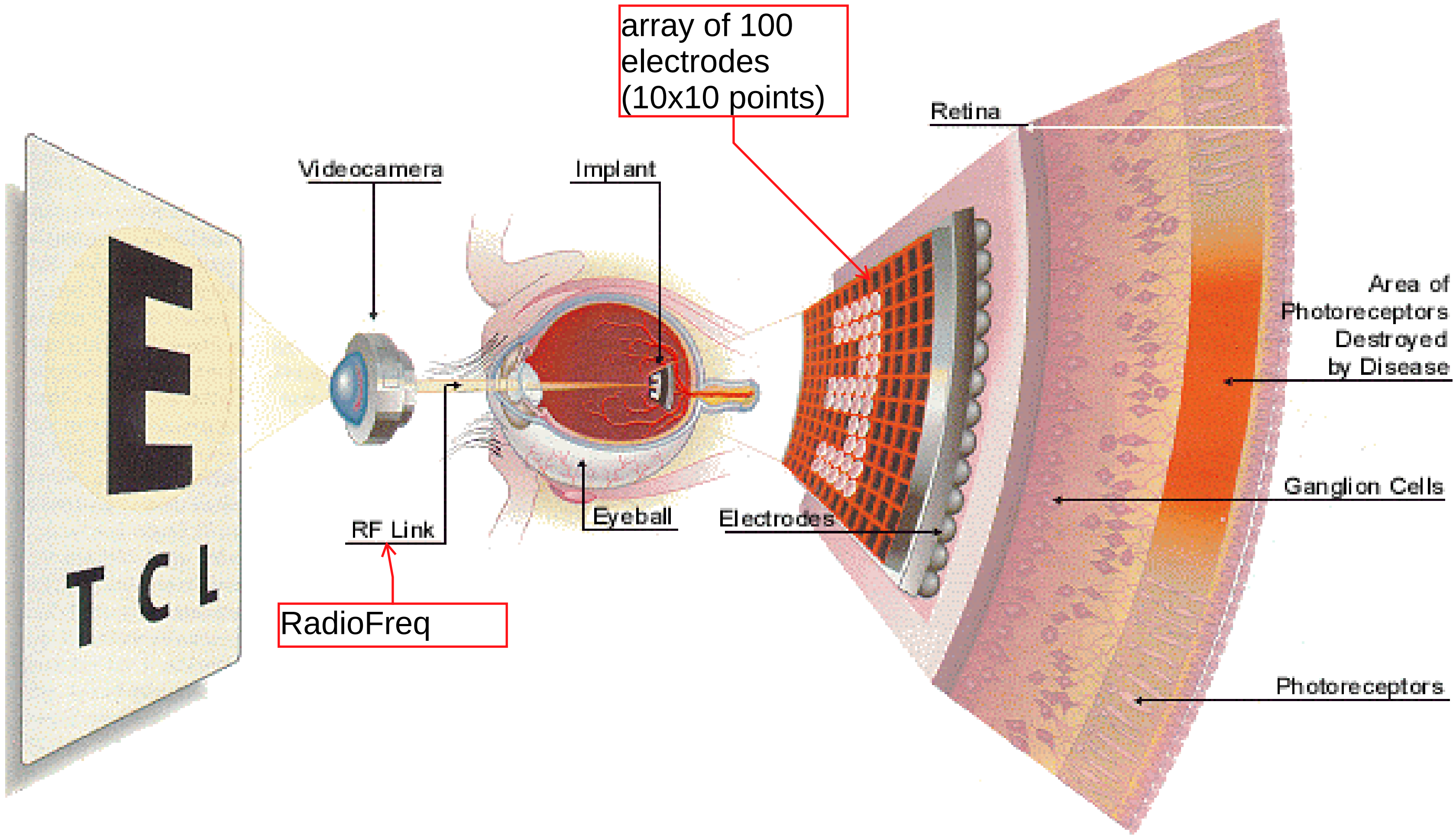
array of el implantend on the cortex

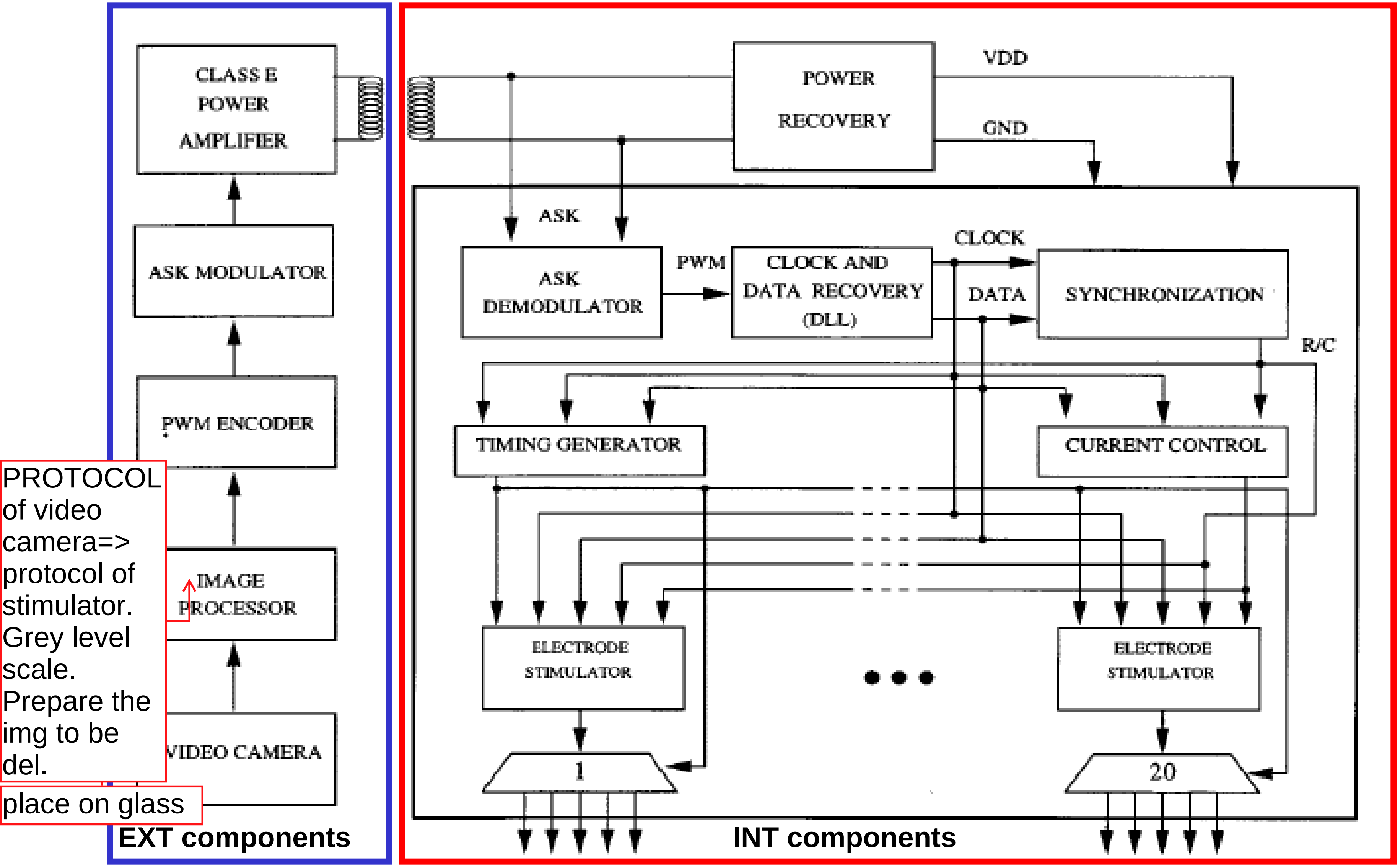
transmitted by RF or transcranial conn.

image processed by external unit

OPPOSITE APPROACH. We stimulate the cortex of the brain, and so it's in the "deepest" layer of the physiology. There's no more "physiology" involved.

Multiple Unit Artificial Retina Chipset (MARC)





IMPLANTED STIMULATOR

(3)The image is encoded with a **4bit data** (10x10). 1 among 16 possibile grey level. Then we have to supply for the internal stimulator, for each of these pixel, a 4bit data. We send a stream of digital words. They are not transmitted as 1/0, but with that PWM encoding. Then it has to be transmitted to the internal chip with RF. It will be AMPLITUDE modulated(ASK).

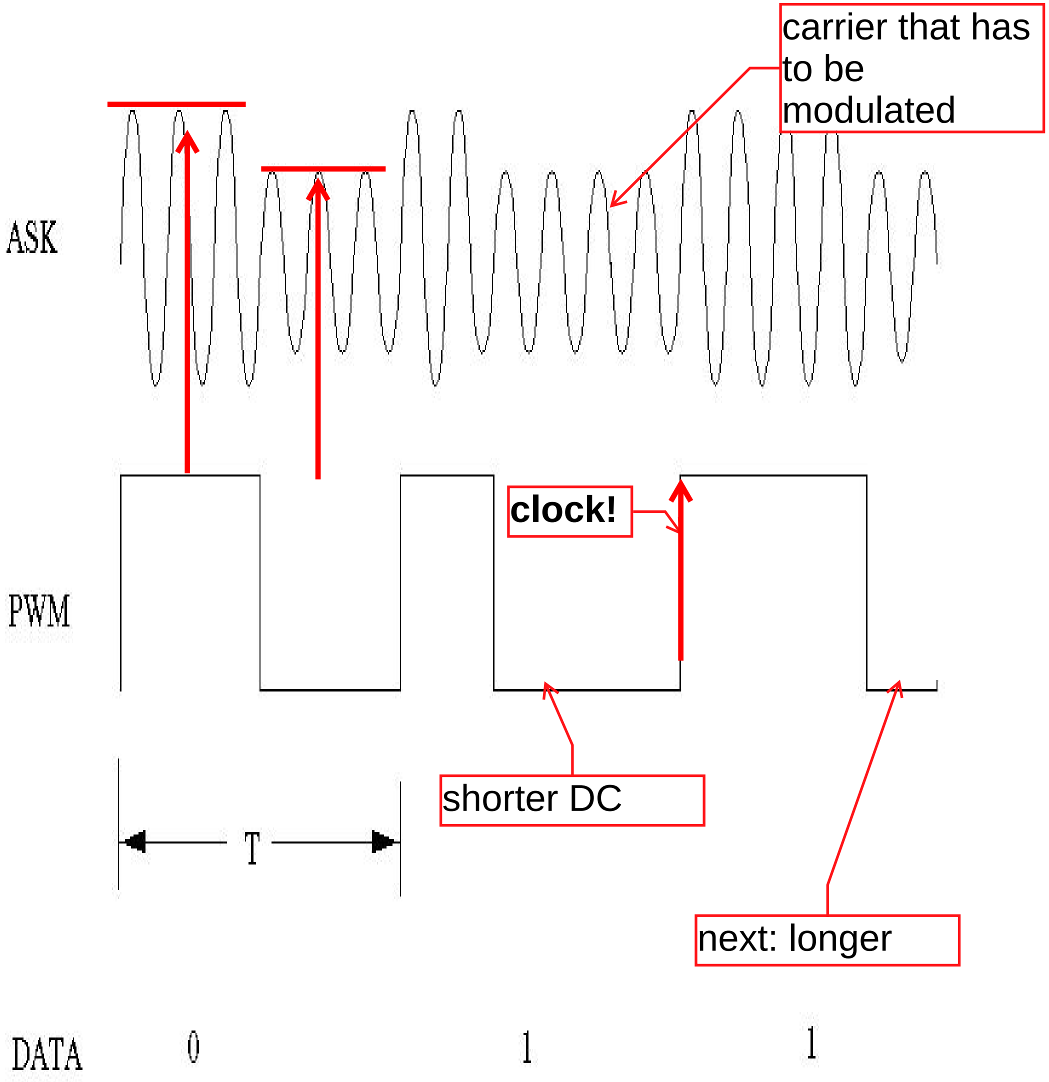
System architecture

fast

- External circuits (located on the glasses)
  - video-camera and hardware to process the images
  - “PWM data encoder” (bit rate from 30 kbps to 600 kbps)
  - “ASK modulator” (carrier frequency from 1 to 10MHz)
  - “power amplifier” and primary coils
- Circuits implanted into the eye
  - “power recovery” (secondary coils, rectifier and others)
  - “ASK demodulator” and decoder
  - circuit to recover Clock and data
  - circuits generators of the stimulus pulses
  - electrodes array

Speed depends on intrisic percepton. We distinguish maybe up to 30fps. We need to refresh the image with a clock that provides this.

Alternate mark inversion encoding scheme:

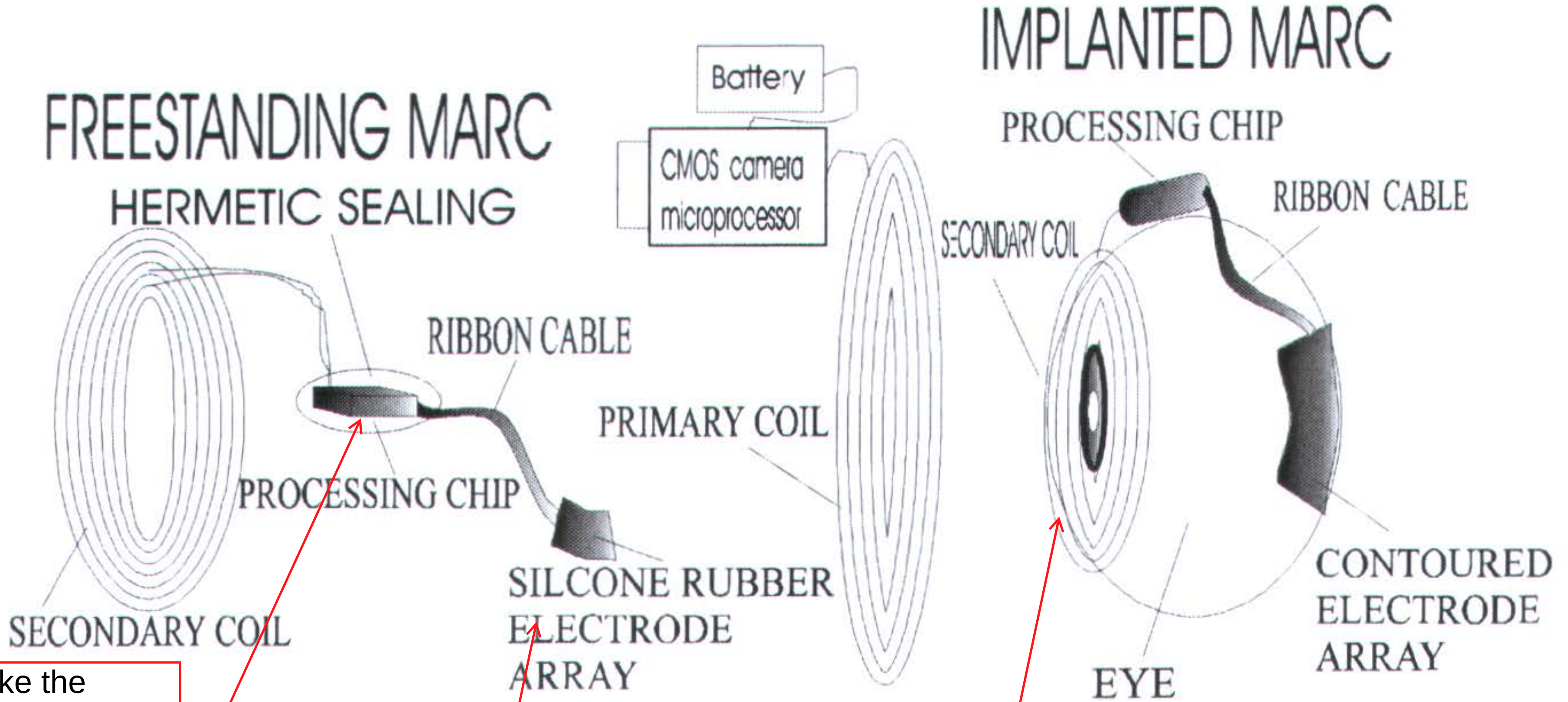


The data are encoded in PWM std:
- 0 is encoded with duty cycle of 50%
- 1 is encoded with duty cycle of 50 +/- Δ% (ex. 60% - 40%) in alternated order

The rising edge of the PWM signal determines the clock signal.

This encoding protocol is used to eliminate the dependence of the recovered power line from the data (which results therefore more stable).

Components of internal part of prosthesis. RF tx/rx is composed by 2 networks which are **resonating** to a given freq. "LC" network where you induce a sinusoidal wave, **freq = 1/(sqrt(LC))**. **Oscillating current in a coil**, the modulating current **produces a variable electromagnetic wave**. The second coil is coupled with the electromagnetic variable, and thus producing a ddp. We basically have an emitting antenna and a receiving antenna. They have to be close in the prosthesis.



make the conversion of carrier into PWM, and then data

supply data into array of electrodes implanted into the retina

receiving antenna, placed here so that is near, max a few mm from primary coil

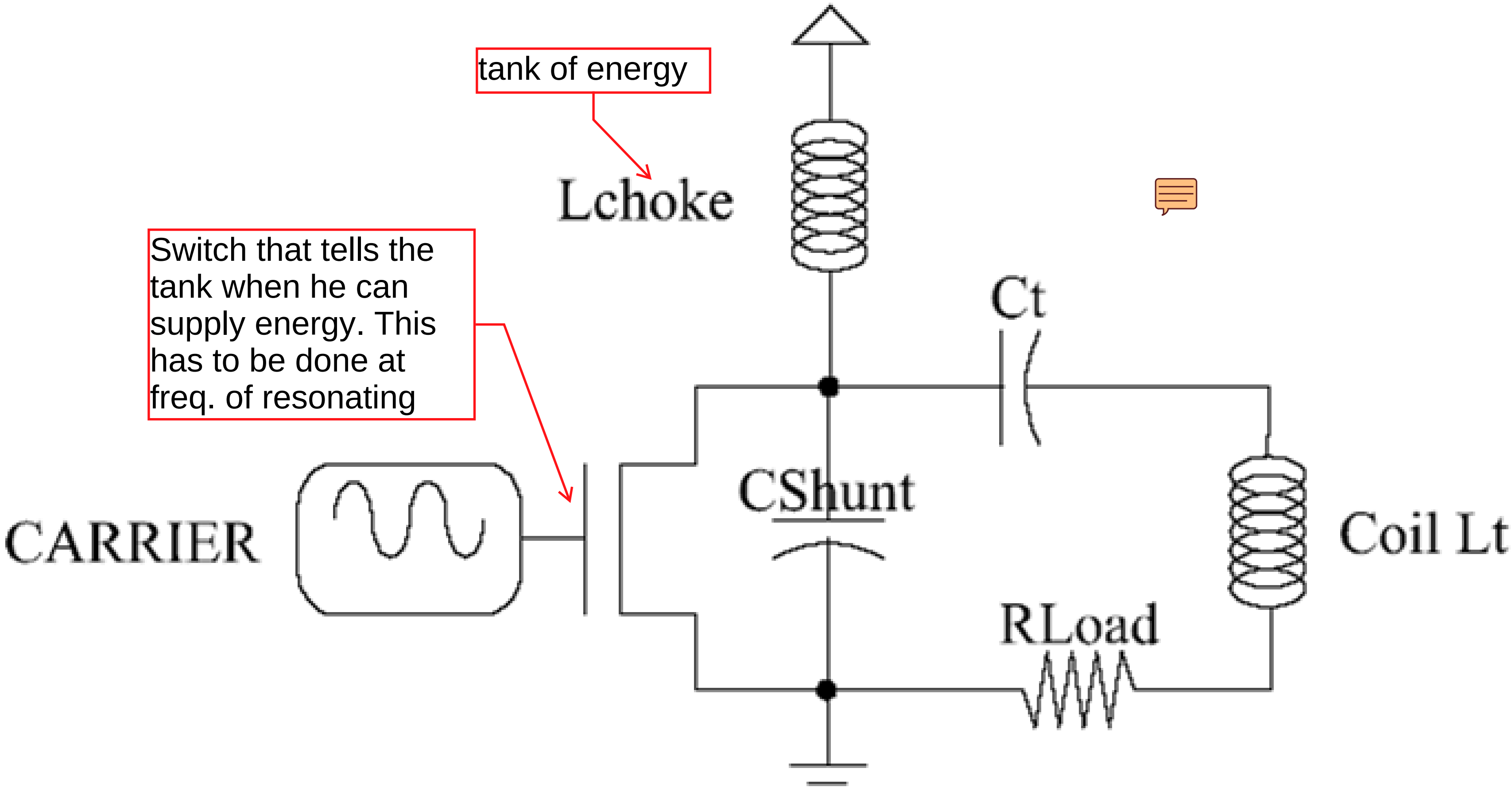
POWER AMPLIFIERs => how the carrier is generated. Simple analysis because it's a lot complicated. Point: we want an LC resonator. **Problem: RF network are not simply LC res**. We start to supply charges over the cap (energy) which bounces on L and back to C.

Class E amplifier

LC RESONATOR

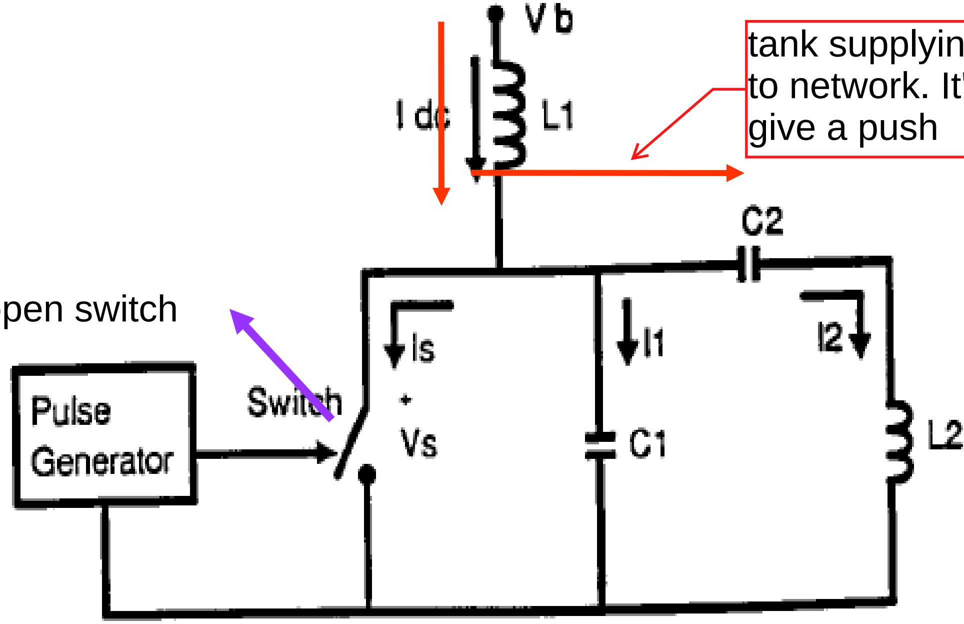
tank of energy

Switch that tells the tank when he can supply energy. This has to be done at freq. of resonating



(2) So we'd have a resonator. This happens in a ideal scenario. In a real scenario we have also R associated to these components. These are PASSIVE components, so the current flowing in R dissipates energy in heat. If we do nothing the osc is estinguished. In order to overcome this we need to connect the CL stage to an el. stage which is continously supplying EN to the system. We need something (transistor stage) that supplies energy to res. => **POWER AMPLIFIERS**. (amp that supplies en to res).

En rifilled / En not refilled

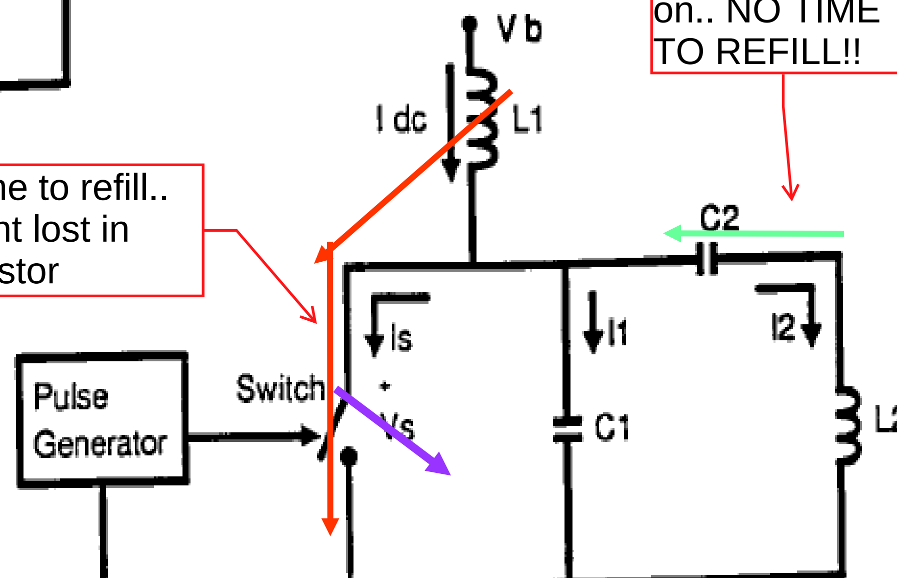


tank supplying current to network. It's time to give a push

open switch

Aperto=> refill

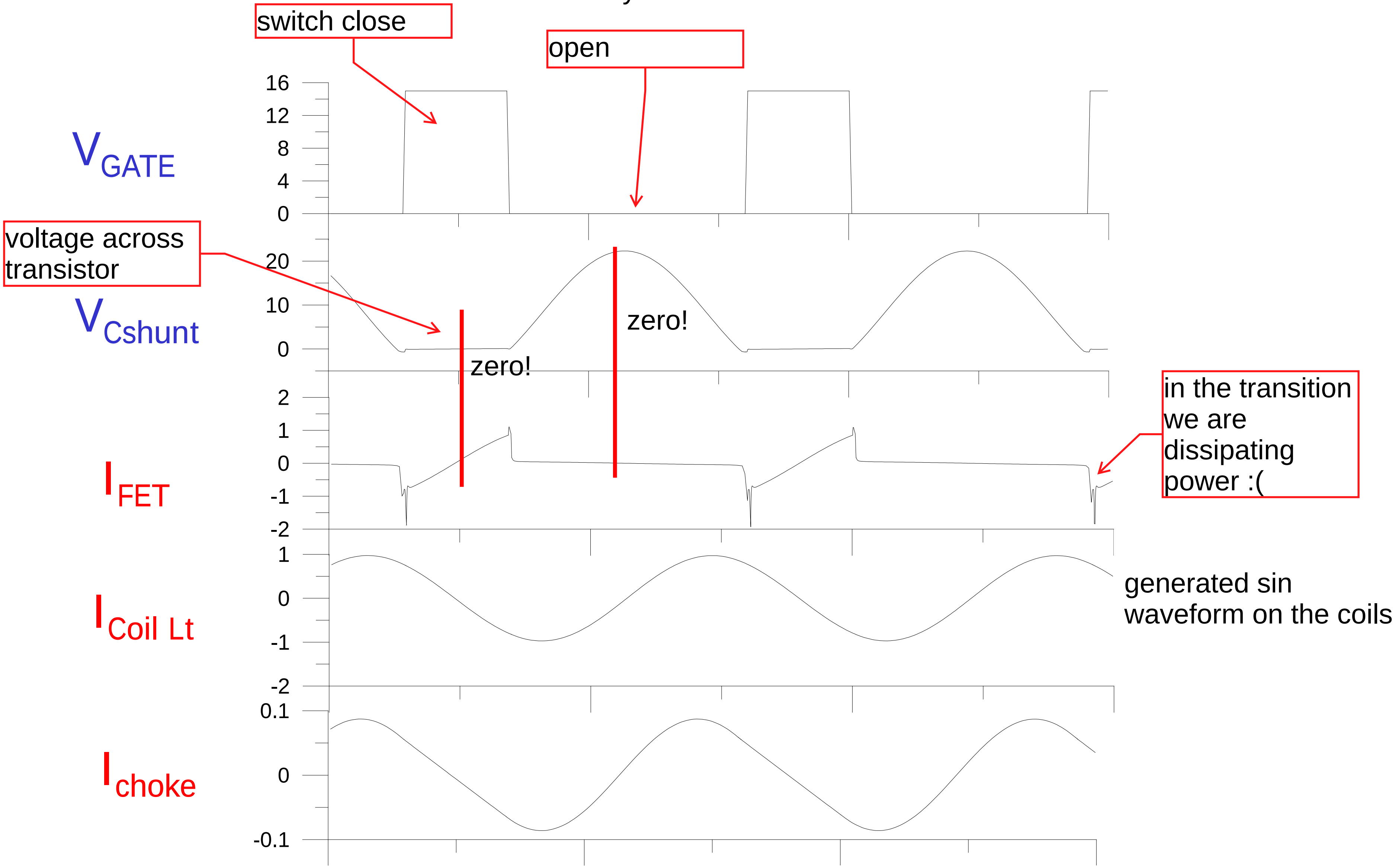
intrinsic current of resonator is supplyin current on the oppositedirection.. NO TIME TO REFILL!!



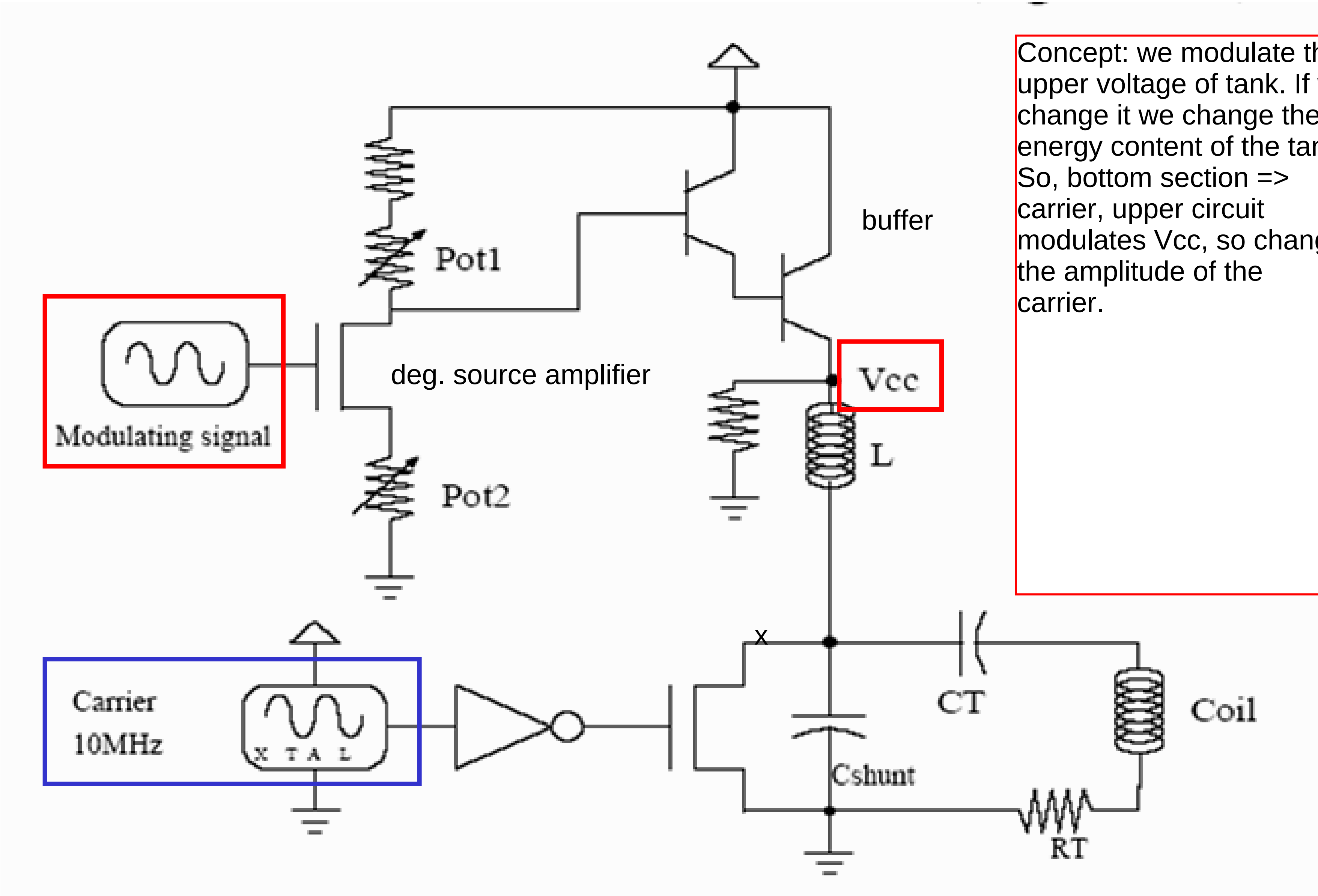
no time to refill.. current lost in transistor

CLASS A,B,C,D,E.... => E: is the "best" class that takes less power of the controlling siwtch. Minimum possible power dissipation of the transistor. Because we want to spend the energy to refill the network! Not spend the coil en. into dissipation energy of the transistor. How is it possible? P=V*I (**across switch**). To have power 0 we can either v->0 when we have I, or I->0 when we have V. We need to design the stage in this way. So when the switch is open is ok any voltage on the transistor (I=0). When it's closed I!=0, but the voltage must be V=0. This happens when it's in the **TRIODE regime Vds~0**.

is it actually a class E?

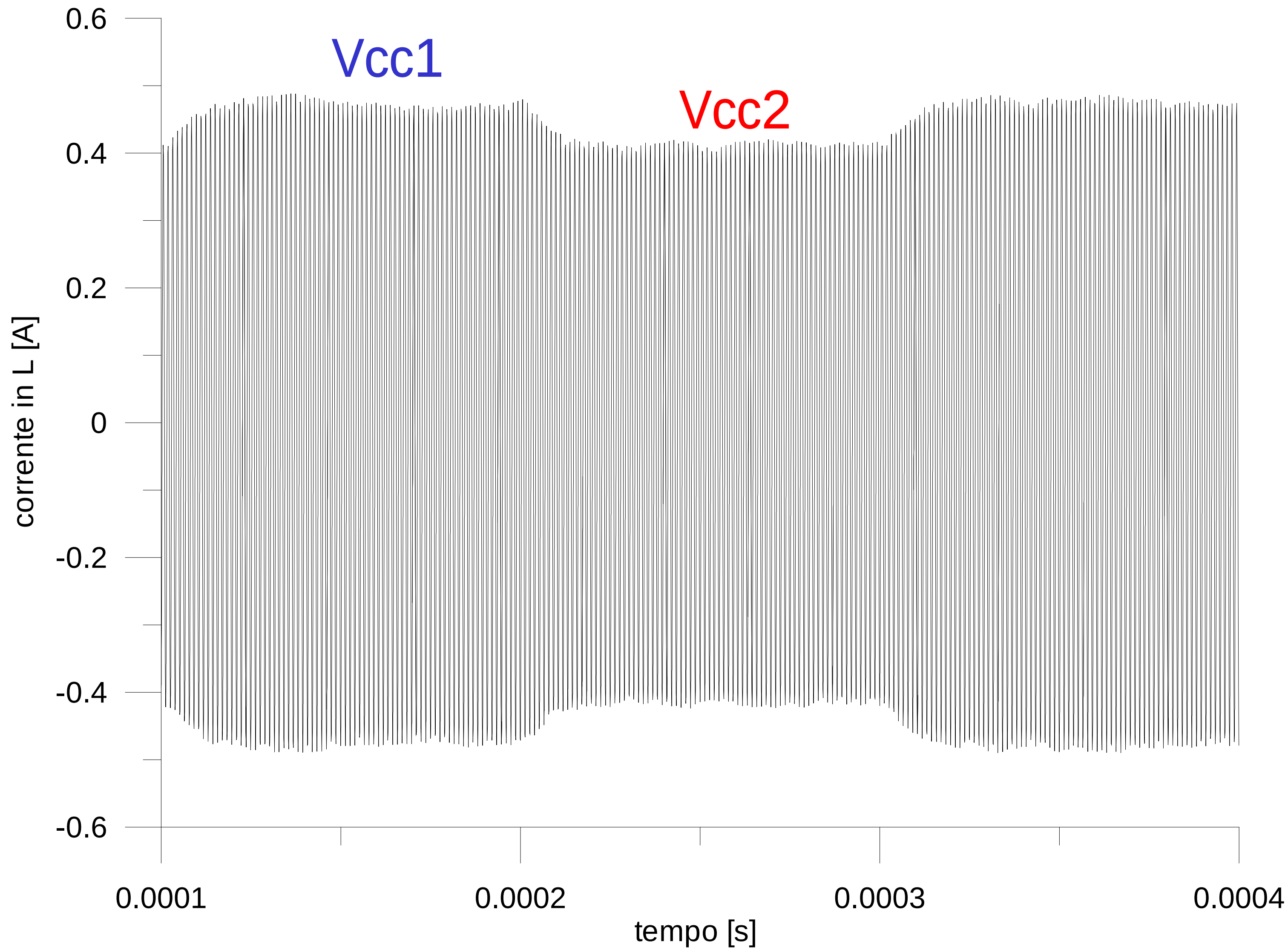


We need also to modulate the carrier



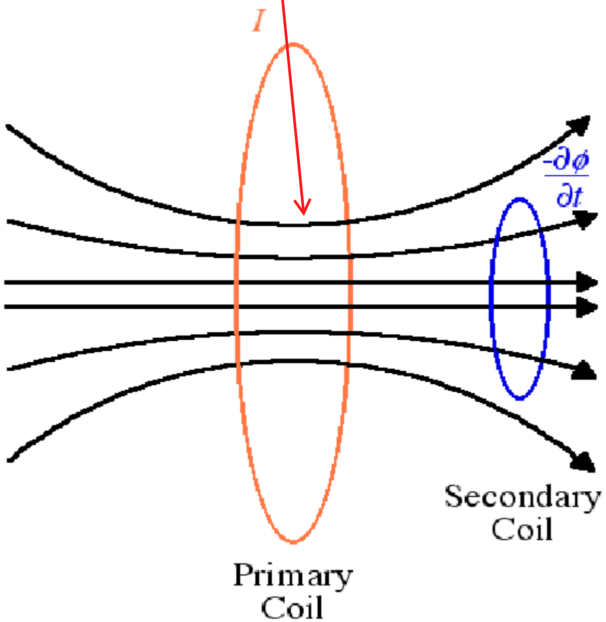
Concept: we modulate the upper voltage of tank. If we change it we change the energy content of the tank. So, bottom section => carrier, upper circuit modulates Vcc, so change the amplitude of the carrier.

Simulation of changing Vcc. We change the amplitude of the carrier. How do we change it? with a PWM.



INTERNAL UNIT

couple



fast

they need to be ofc parallel, and they should be as close as possible, to maximise field coupling

voltages across secondary coil depending on distances between the two

pratically no more coupling and voltages

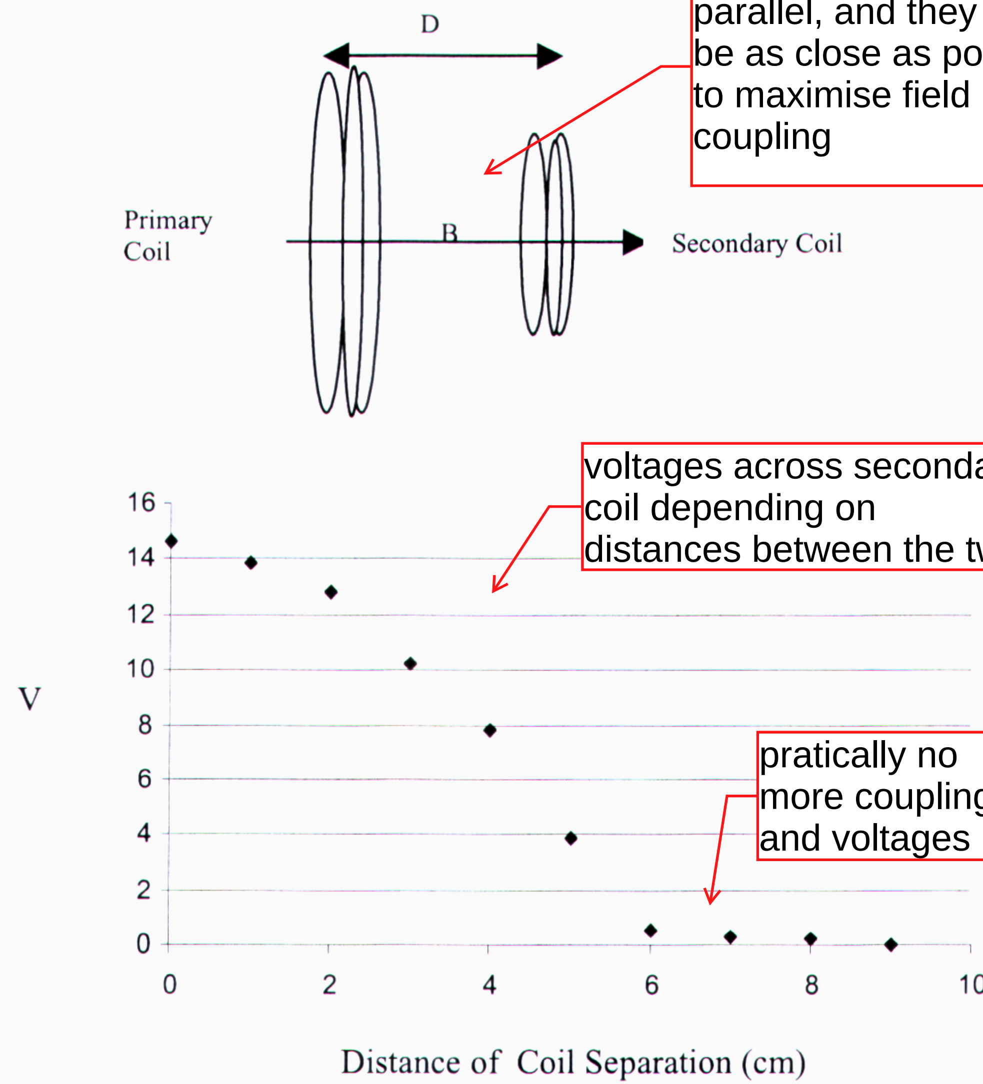
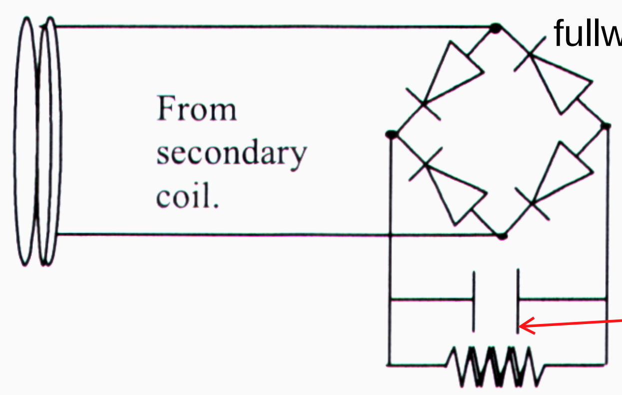


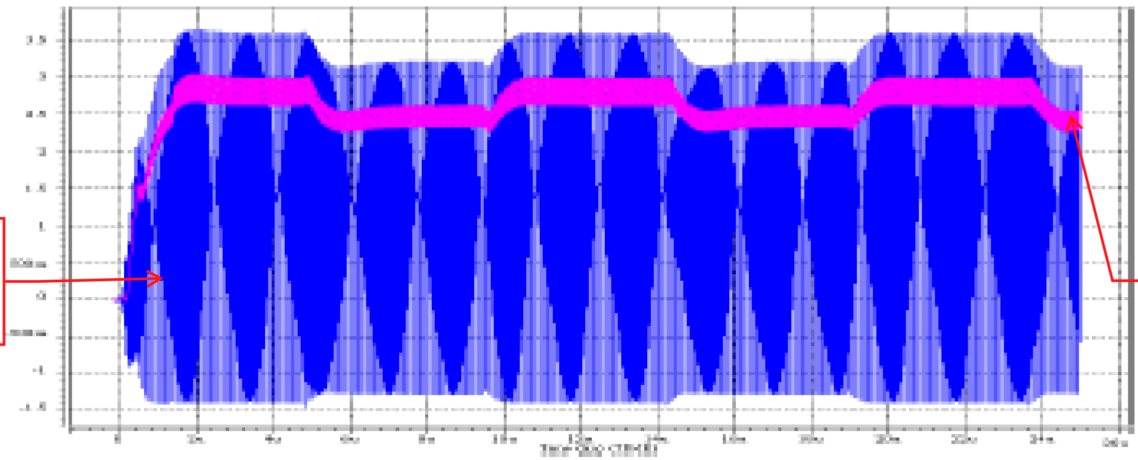
Figure 13B. Voltage vs. axial coil displacement.

Envelope detector
(and recovery of the circuit power line)



we take the env of sin waveform

Figure 13A: Full-wave rectification of MARC2 telemetry signal. V_R is measured across a 1K resistor.

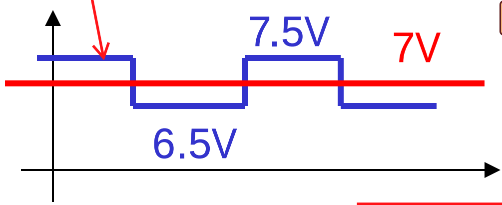


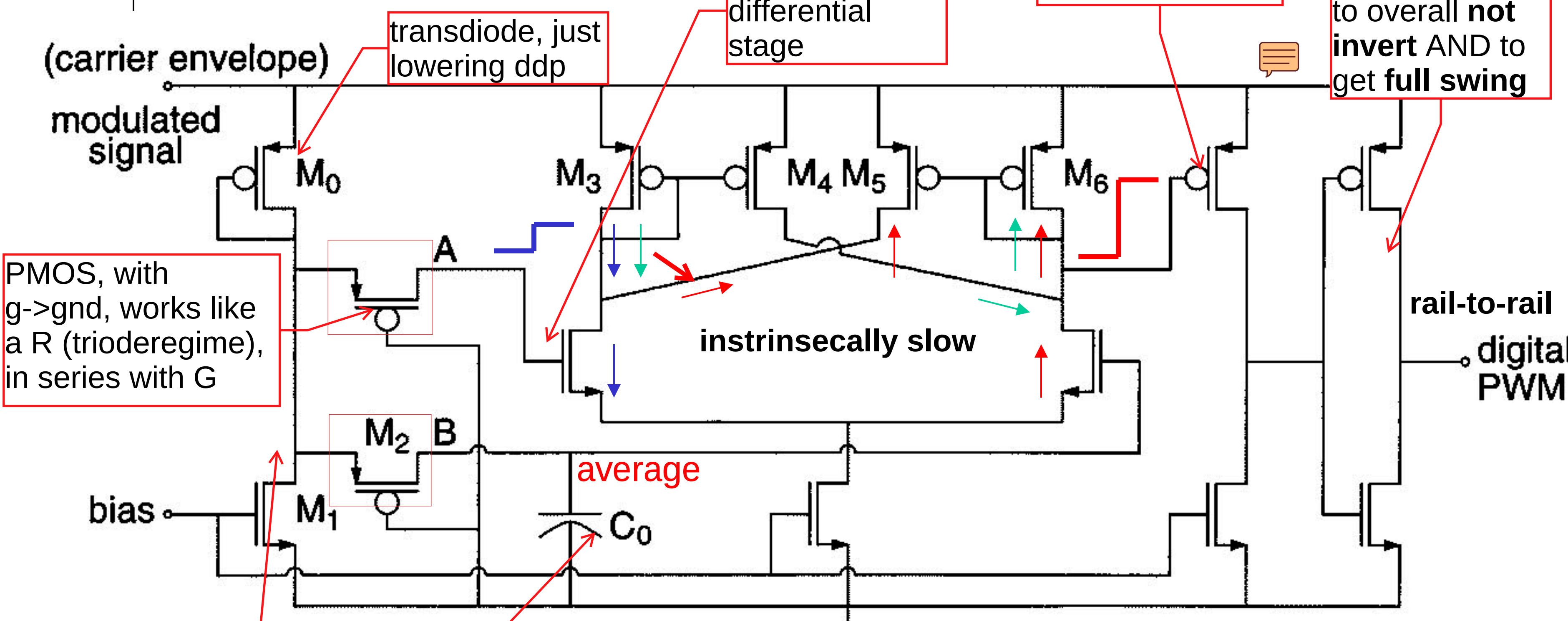
blue => voltage at the secondary coil

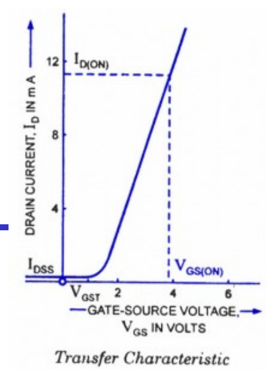
effective voltage (envelope). It's ddp > 0, can be used as power supply. It still has a ripple. If we want more stable we just increase C. But we don't really need a perfect ultrastable vdd (see next slide). If it has the pwm info it wont be a problem

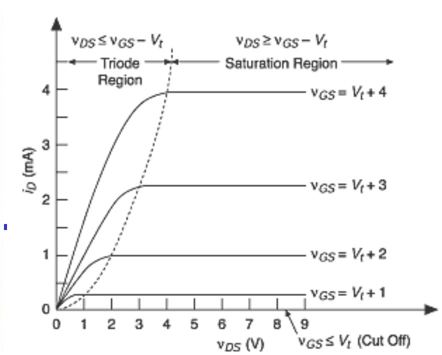
ASK demodulator

goal: transform the envelope signal to a pure PWM signal, which is 0-Vdd.
Following stage, from PWM to digital signal.





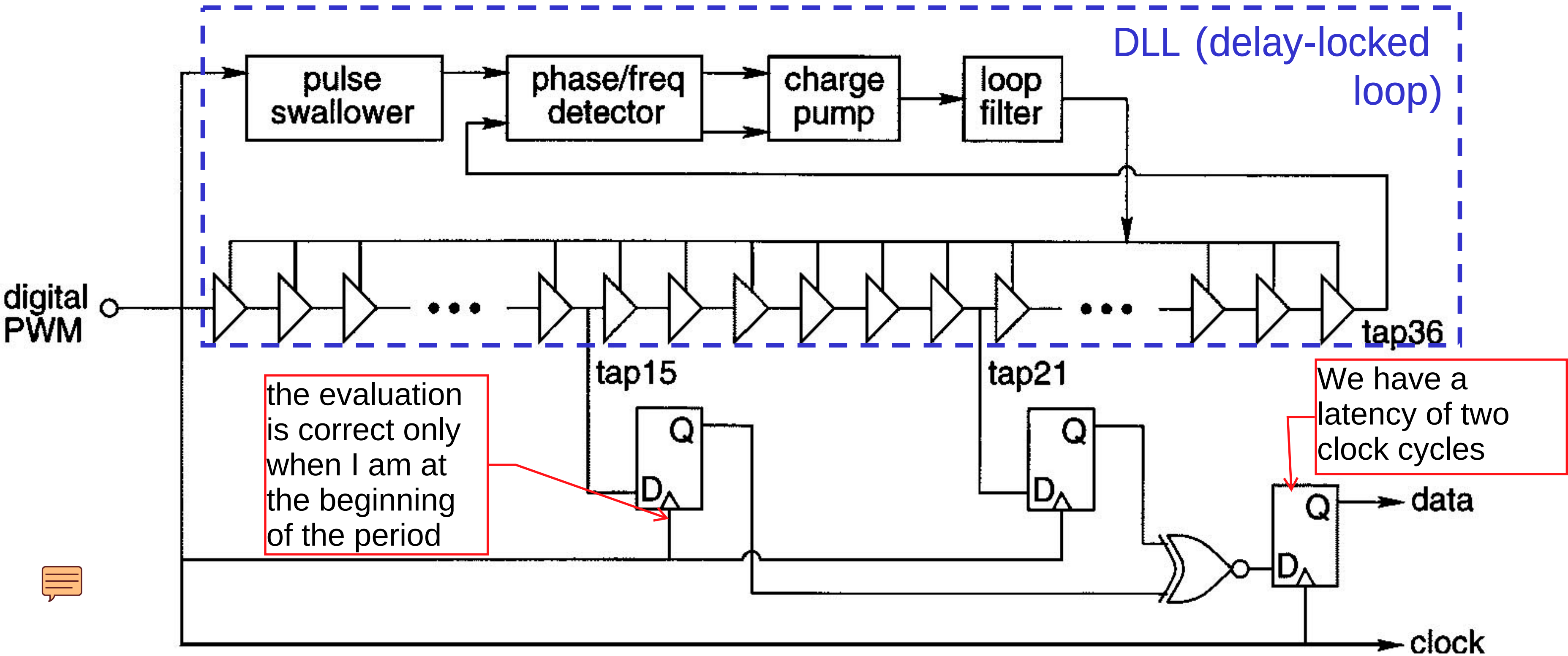




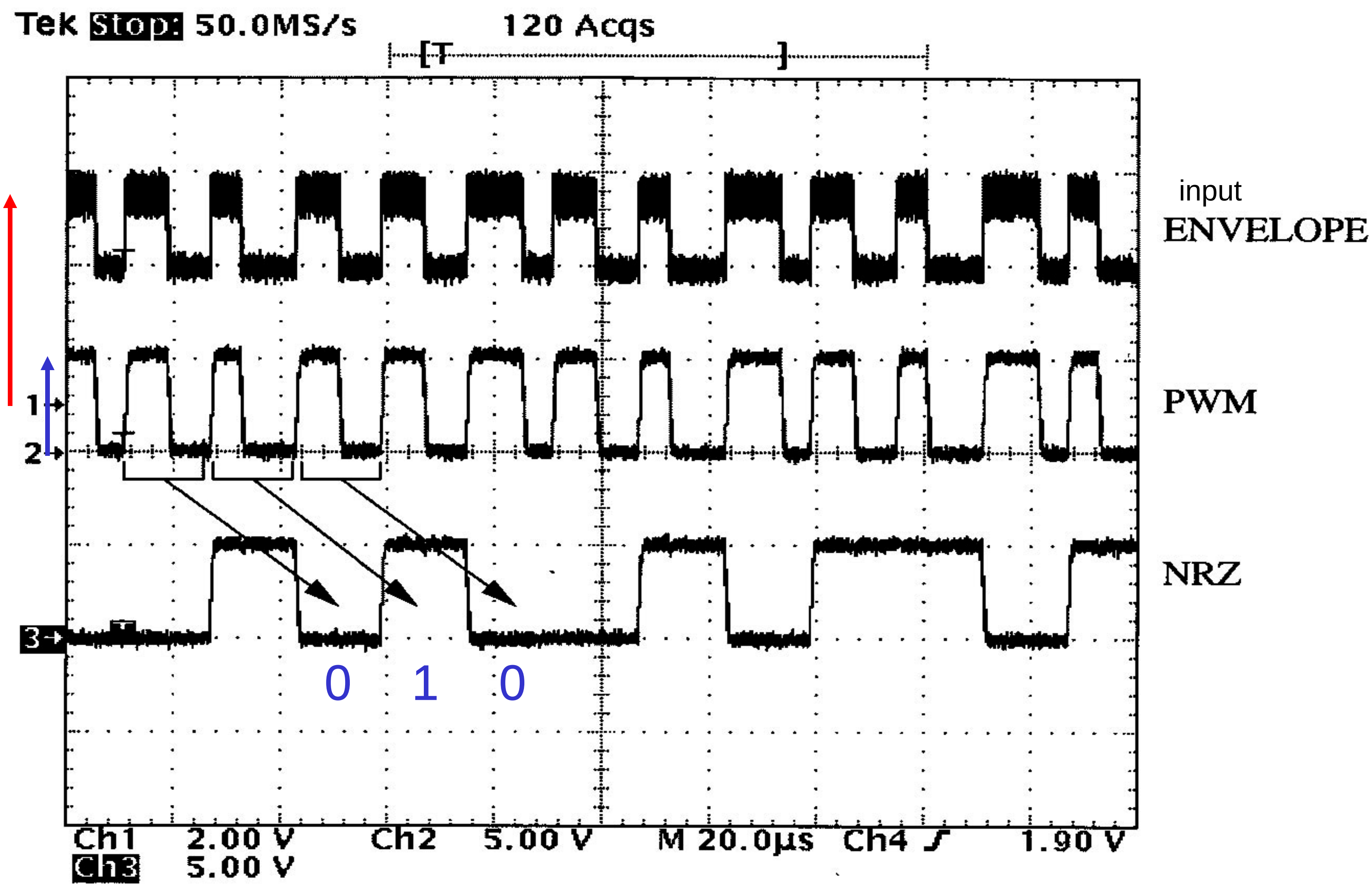
Electronics Design for Biomedical Instrumentation
Prof. Carlo Fiorini

We have the true PWM. Now we need sequnce of 0/1 AND the clock

Clock and data recovery circuit

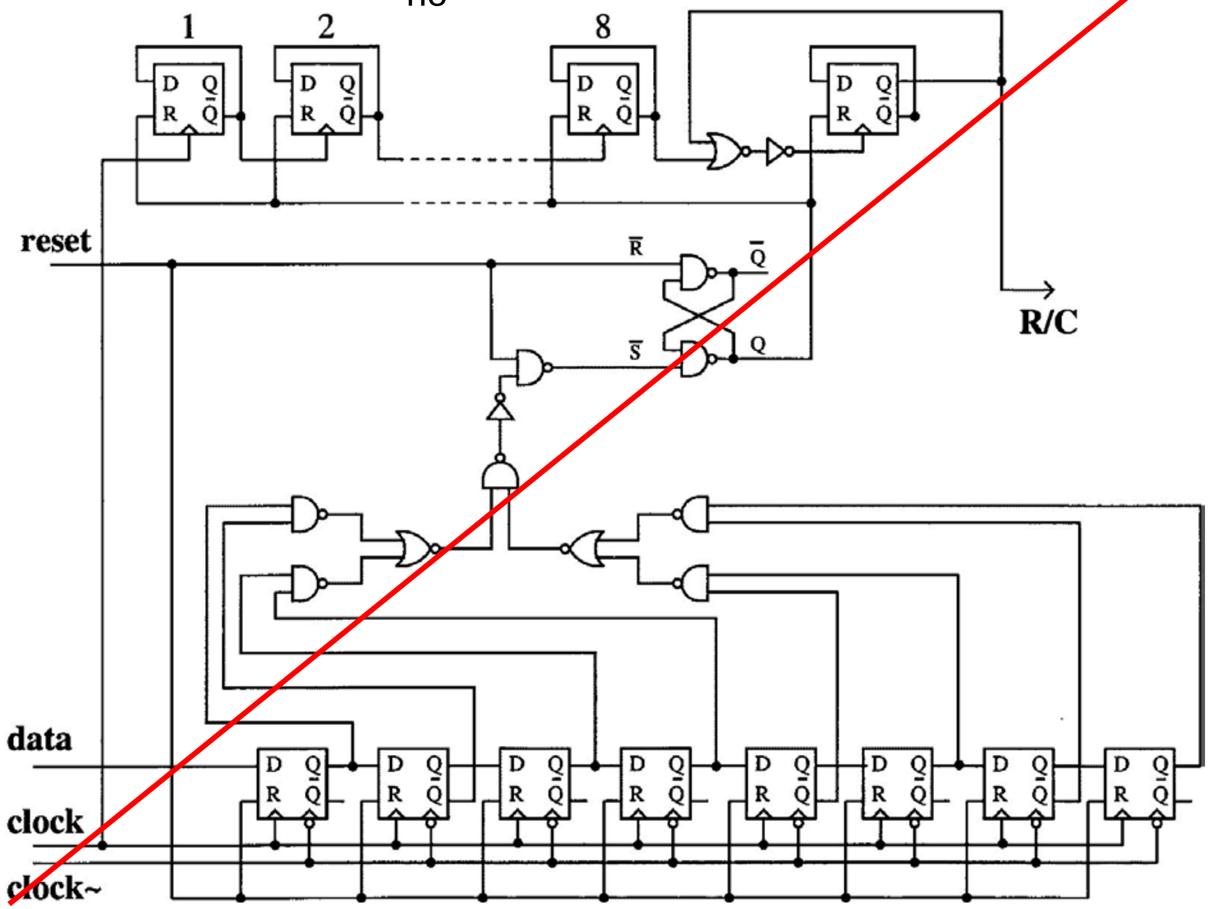


- clock is obtained through rising edges of the PWM waveform
- DLL is locked to the PWM period (positive edges)
- period is divided into 36 intervals with equal delay
- XNOR provides a “1” only if outs 15 and 21 are “1” (duty cycle 60% or “0” (duty cycle 40%), a “0” if 21 is “1” and 15 is “0” (d.cycle 50%)


Tek Stop: 50.0MS/s
120 Acqs
T
input
ENVELOPE
PWM
NRZ
1
2
3
0
1
0
Ch1 2.00 V
Ch2 5.00 V
M 20.0µs
Ch4
1.90 V
Ch3 5.00 V

Synchronization circuit

no



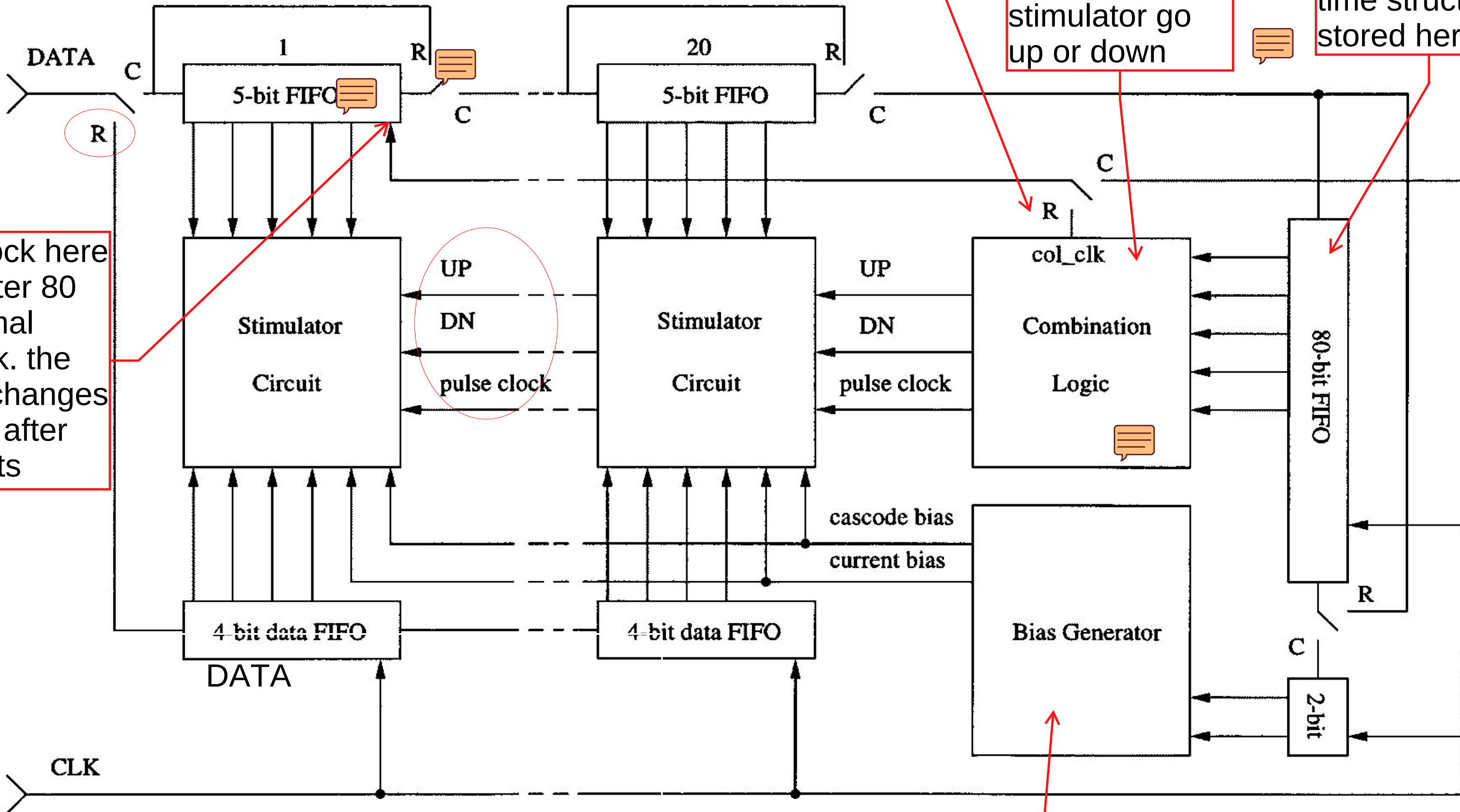
It acknowledges a known sequence (key) and switches the chip from the configuration state (C) to the running state (R)

Il clock dei 5bit è dato da questo blocco che lo estrapola dall'80, probabilmente come rising

says to the stimulator go up or down

time structure stored here

1 clock here is after 80 normal clock. the fifo changes only after 80bits



DATA

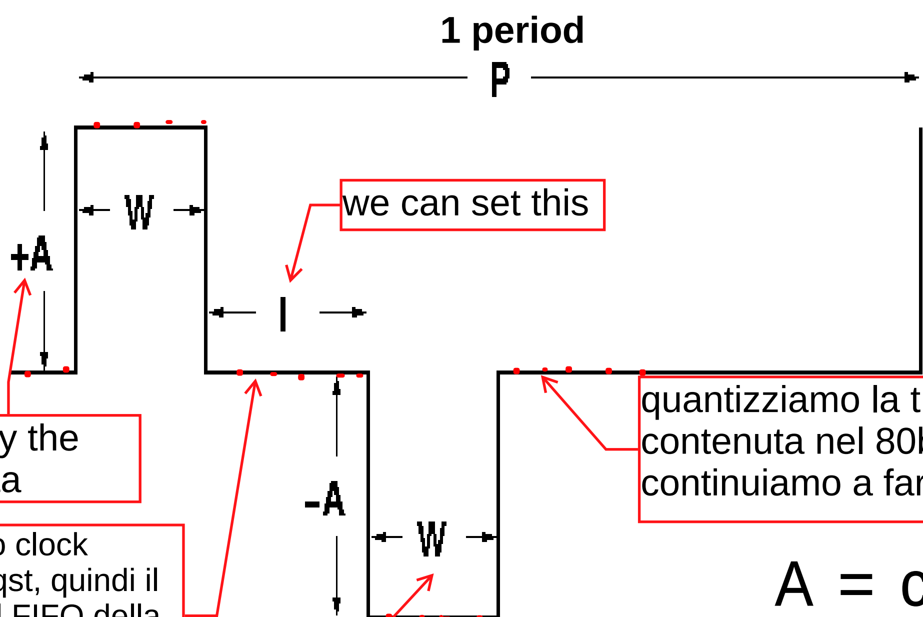
The circuit purpose is to set the stimulating pulse parameters (timing and current intensity).

By changing the switches status (R/C) it switches from the configuration to the stimulation (RUN) state.

An additional 2 bit register specifies the used current range (200, 400 or 600 μA).

full scale range setting, driven by 2bit

Parameters of the pulses to apply to the electrodes



we can set this

given by the 4bit data

1 singolo clock cambia qst, quindi il clock del FIFO della selz. elettrodo sarà molto più lento

We can regulate this

quantizziamo la time structure in 80 clock step, contenuta nel 80bit FIFO; che è loopato quindi continuiamo a fare delivery della sequence

(4)Timing sequence supplied to the stimulator. Positive and negative lobe. Only the negative actually provides the AP. There's also a positive b/c we dont want to inject charge always with the same polarity. We want to stimulate the tissue providing charge in one direction but also take it in the other. [KEEP CHARGE NEUTRALITY]

We can set also the amplitude **full scale range. Within this we'll have 16 gray level.**

A = current amplitude (from 10μA to 600 μA)

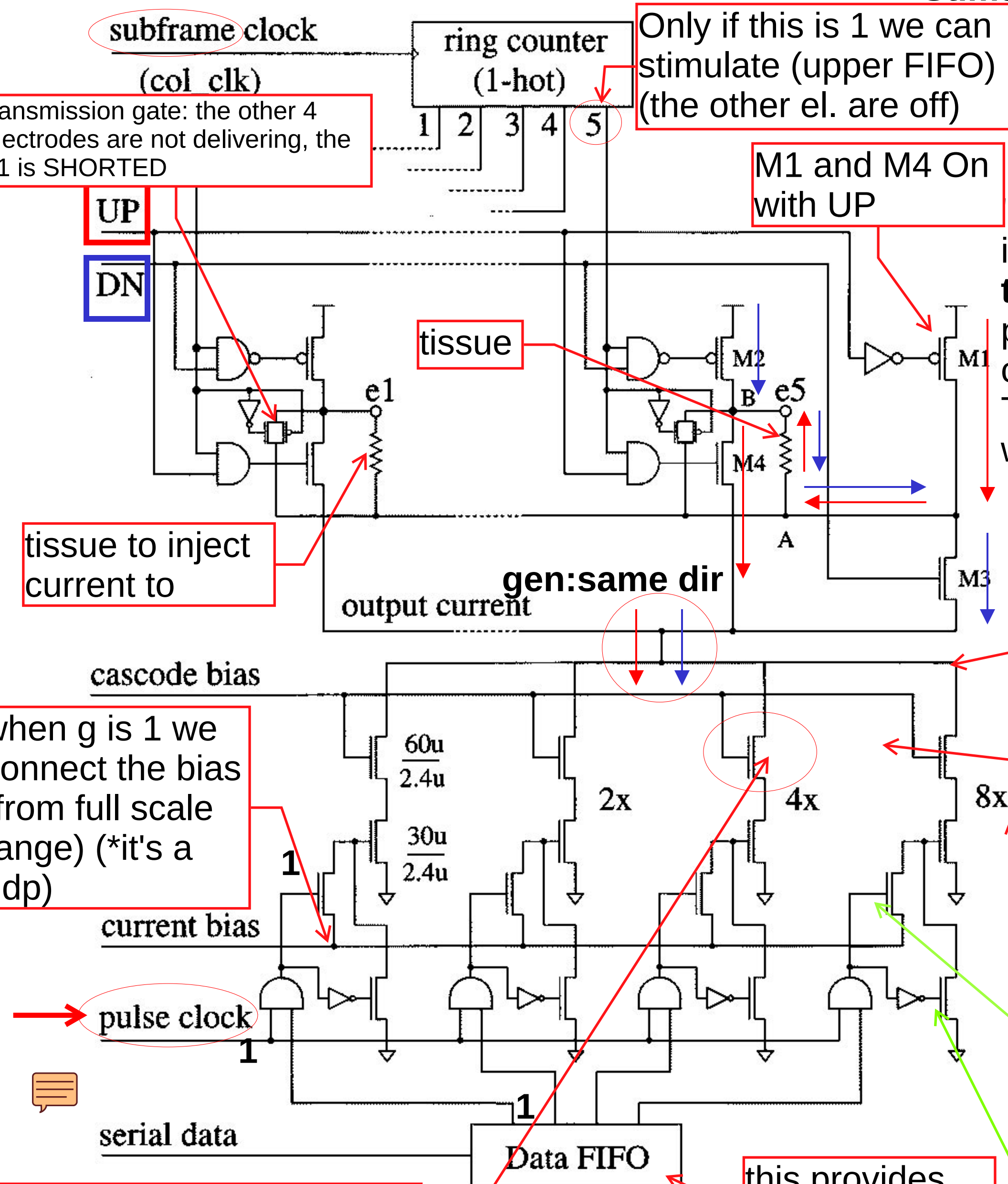
W = pulse duration (from 0.1ms to 2ms) e.g. of configuration of duration

P = pulse period (frequency from 60 to 500 Hz)

Stimulation circuit

Pulses generation circuit

'smart" current gen., needs to circulate the current in the tissue (resistor e1 and e5). **The current has to go in one direction and then in the other**, so pulse UP and DOWN. Both are logic level up, but changes the direction of circulation.
The bottom part is a current generator implemented with a 4bit DAC. We have 16 gray level of current.



Only if this is 1 we can stimulate (upper FIFO) (the other el. are off)

transmission gate: the other 4 electrodes are not delivering, the e1 is SHORTED

M1 and M4 On with UP

tissue

tissue to inject current to

gen:same dir

at the end: sum of current, with 16 different levels

we have in parallel 4 generator, each the double of previous one => dac. Each one is activated/deact. by a switch (4bit data line)

when g is 1 we connect the bias (from full scale range) (*it's a ddp)

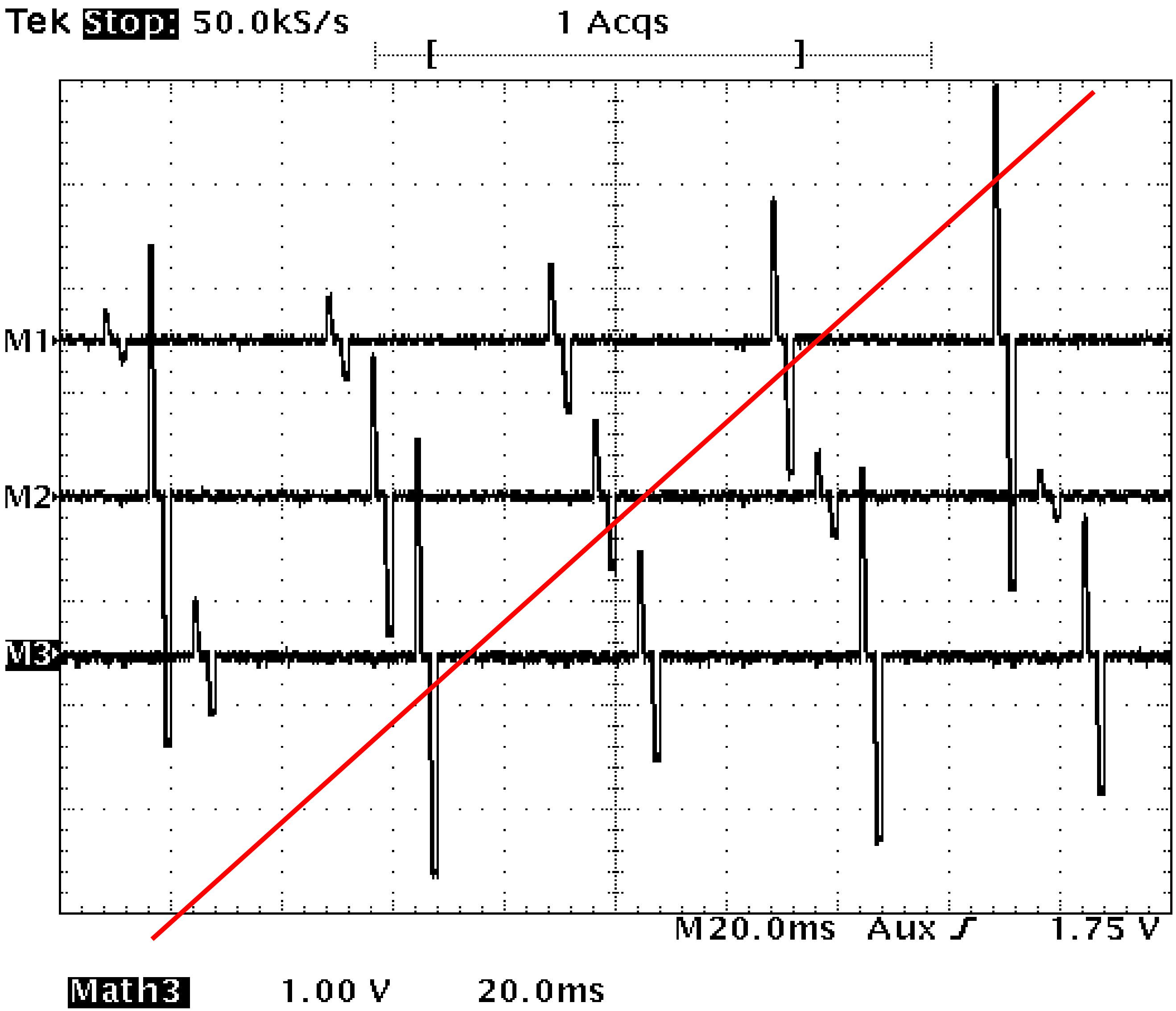
each branch has a transistor twice as large

if 0 this is closed

this becomes 1, and brings the gate to gnd

this provides on/off

*cascode stage! Current buffer. Signl. output high impedance, input low no

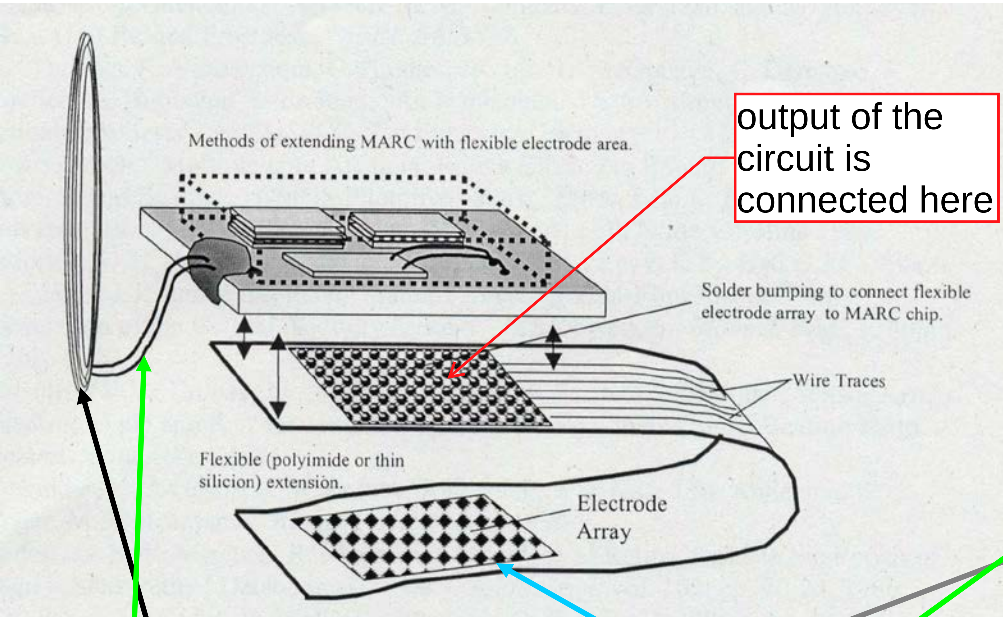


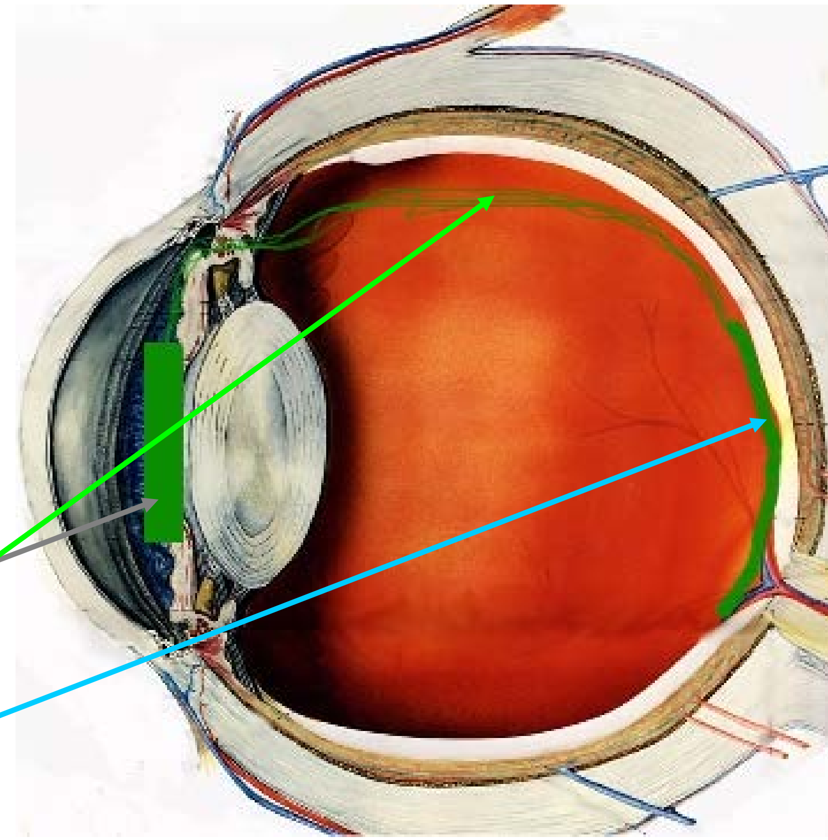
Tek Stop: 50.0kS/s
1 Acqs
M1
M2
M3
M20.0ms Aux ∫ 1.75 V
Math3 1.00 V 20.0ms

Components implanted in the MARC system

fast

Position of the MARC system in the eye

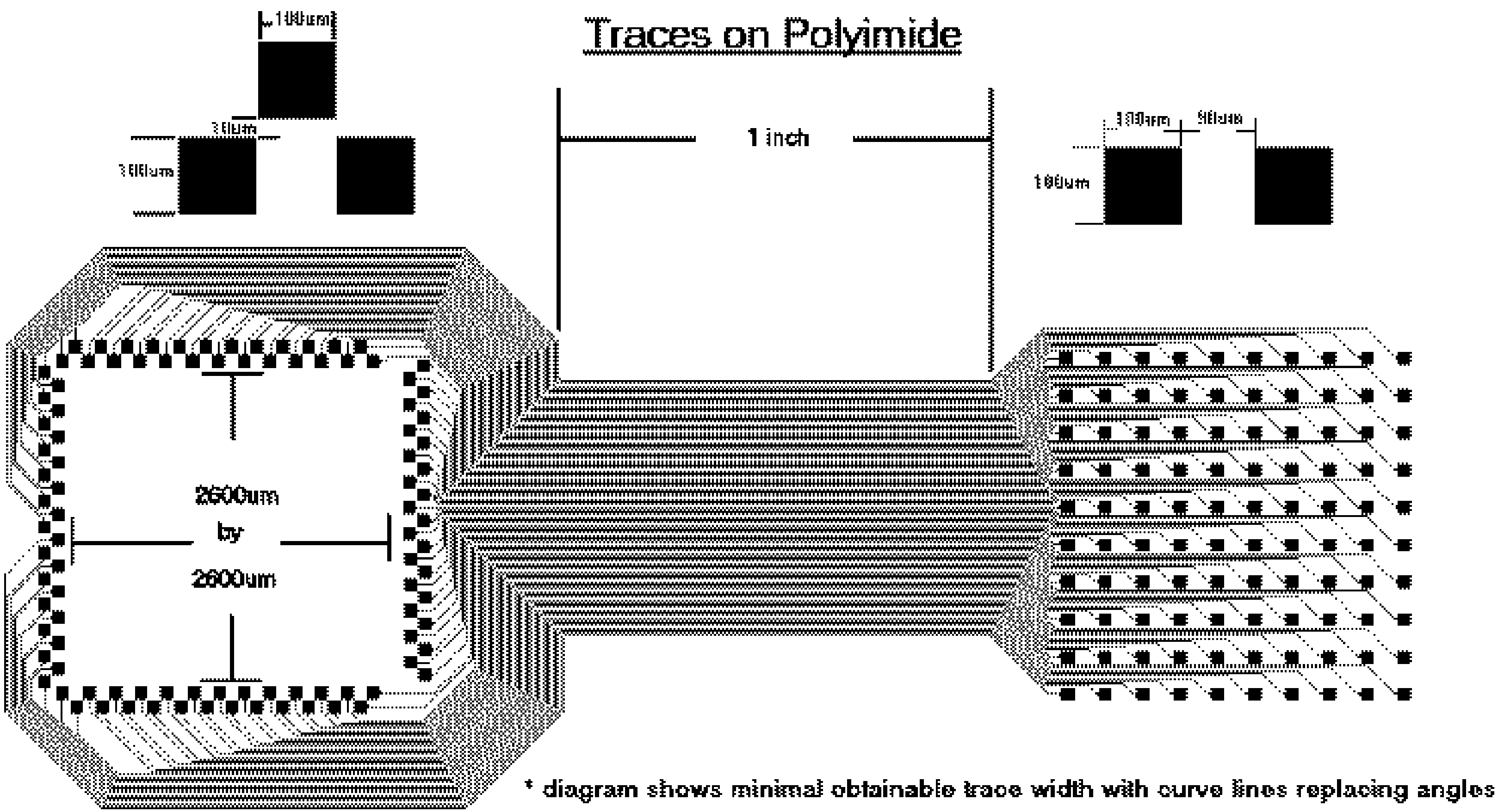




Secondary coils

Cable for the signal transfer

Internal chip and electrodes array


Traces on Polyimide
1 inch
2600um
by
2600um
* diagram shows minimal obtainable trace width with curve lines replacing angles