Electronic Visual Prosthesis

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Abstract

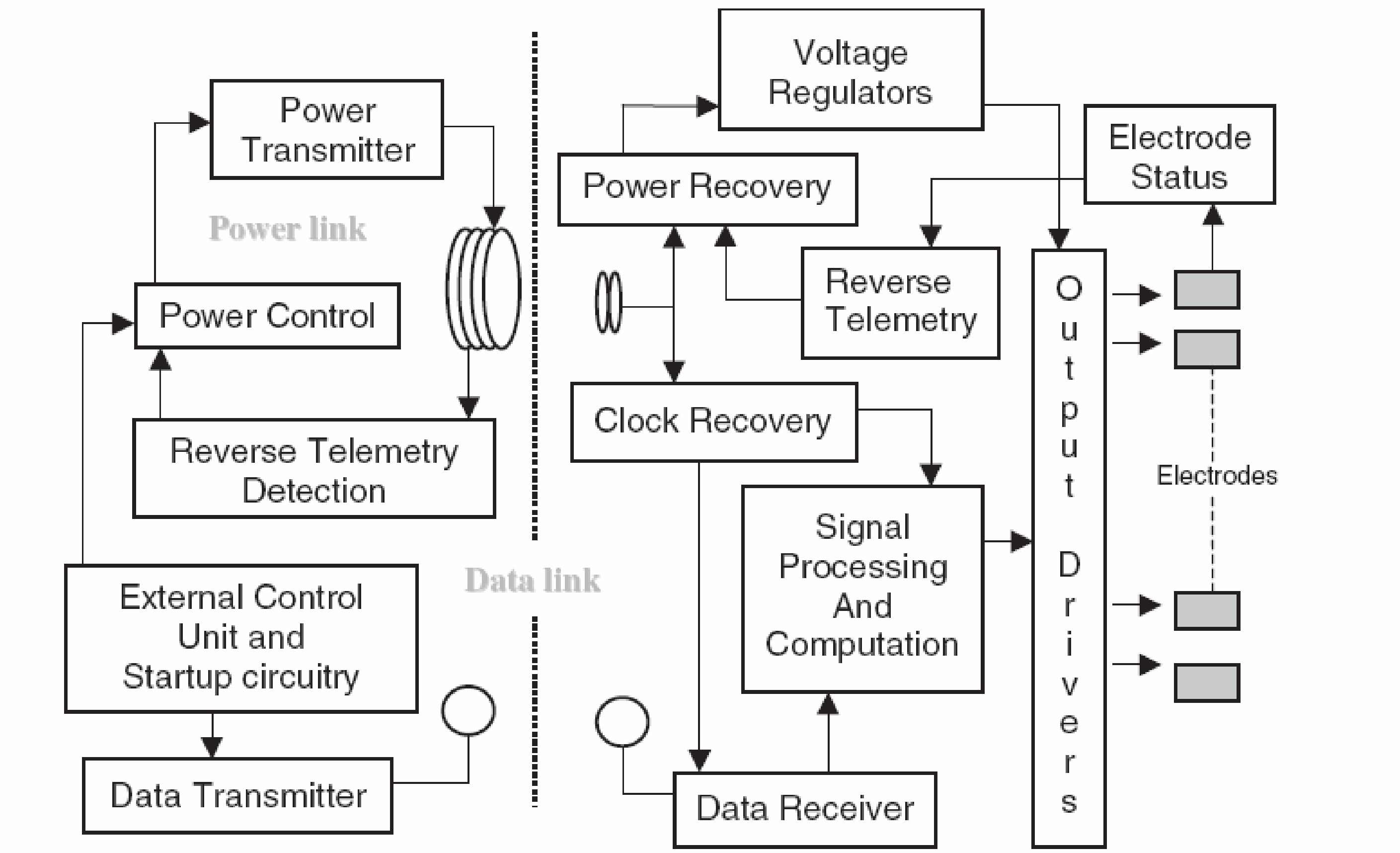
- Visual Loss
  - Caused by RP and AMD
- Why IC?
  - Electrical stimulation may restore vision.

Evolution of the chips

Retinal chip	Salient features
Retina-1	5 × 5 Photo sensor array and current drivers; 2.0 μm CMOS technology
Retina-2	Photo sensors at the external side of the eye; 100 channels with 20 drivers (1 : 5 multiplexing); 2.0 μm CMOS technology
Retina-3	Additional circuitry for data recovery from PWM data link using ASK demodulator and DLL: AMI 1.2 μm technology
Retina-3.5/3.55	60 dedicated drivers; 2 independently programmable binary weighted DACs; error detection through CRC and check sum
Retina-4	Reduction of area using multibias DAC replacing the binary weighted DAC

FIG. 1. Evolution of the chips, Retina-1/2/3/3.55/4 (clockwise from top left).

System block diagram

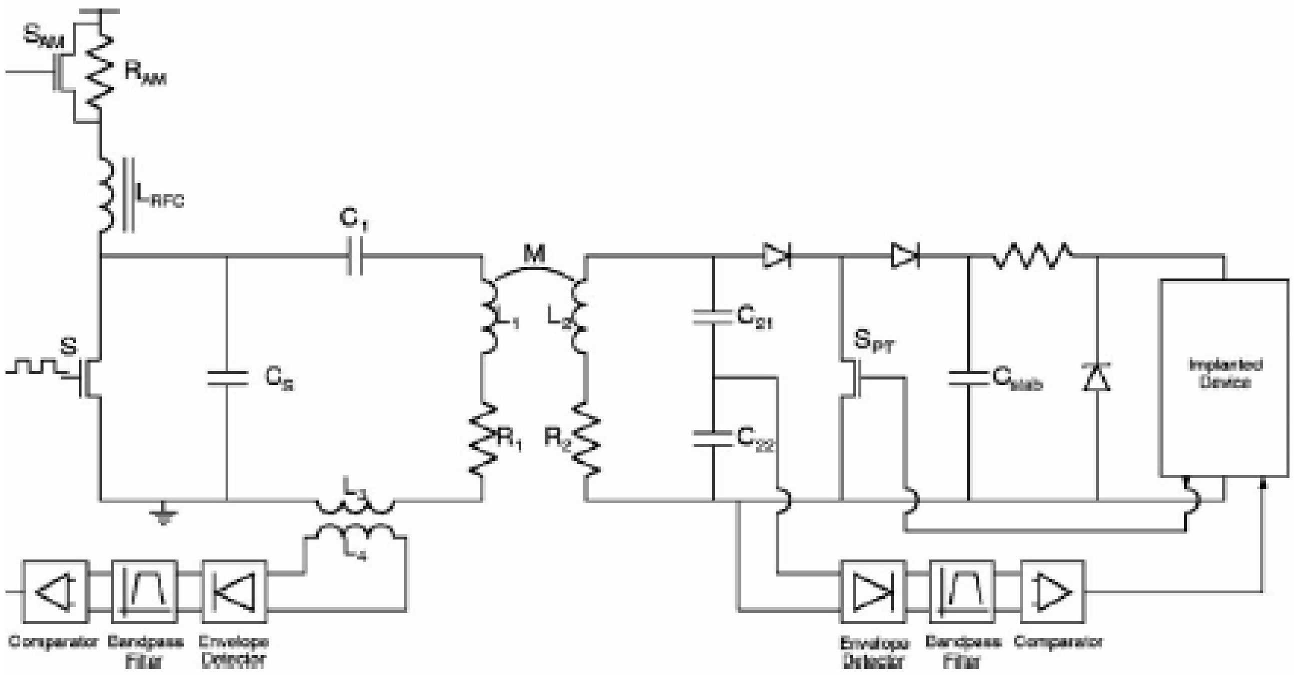


Telemetry

- Percutaneous connectors
  - Increasing the risk of infection.
- Solution
  - Partitioning the prosthesis into parts that are internal and external to the body.
  - Wireless link is a viable approach.
  - Magnetic coupled coils are used.

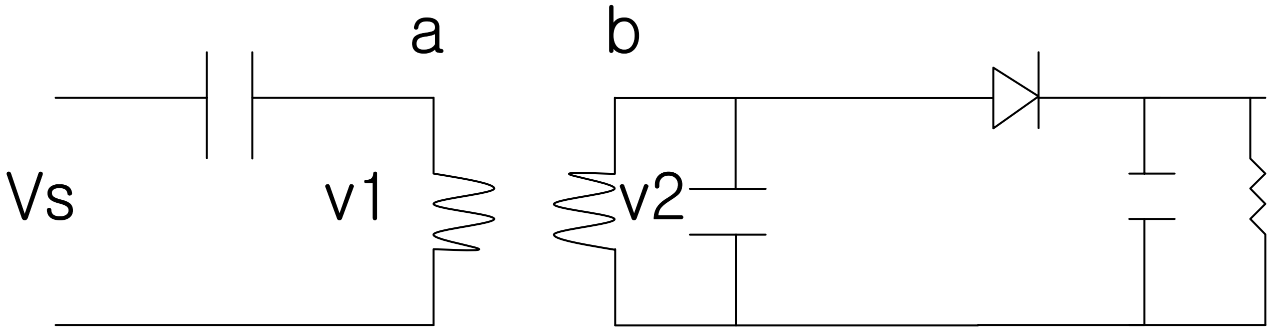
Frequency

- Class E amp
- Resonant frequency



Forward telemetry

Ideal case -> K=1

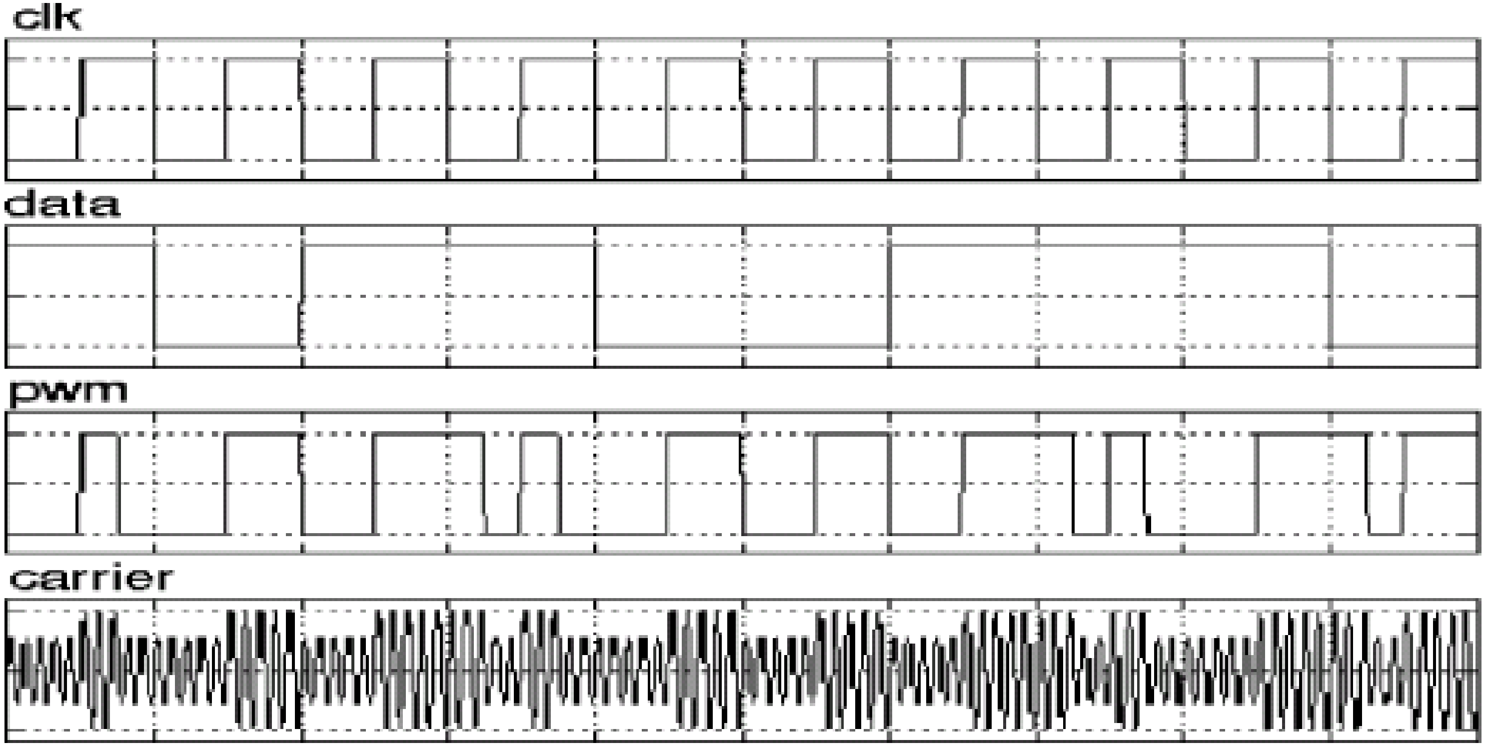


$$V1/a=V2/b$$

$$V2=(b/a)V1=Vs*[(a/b)*(1/jwc2)]/[(1/jwc1)+(a^2/b^2)*(1/jwc2)]$$

Forward Encoding Method 1

- ASK with PWM

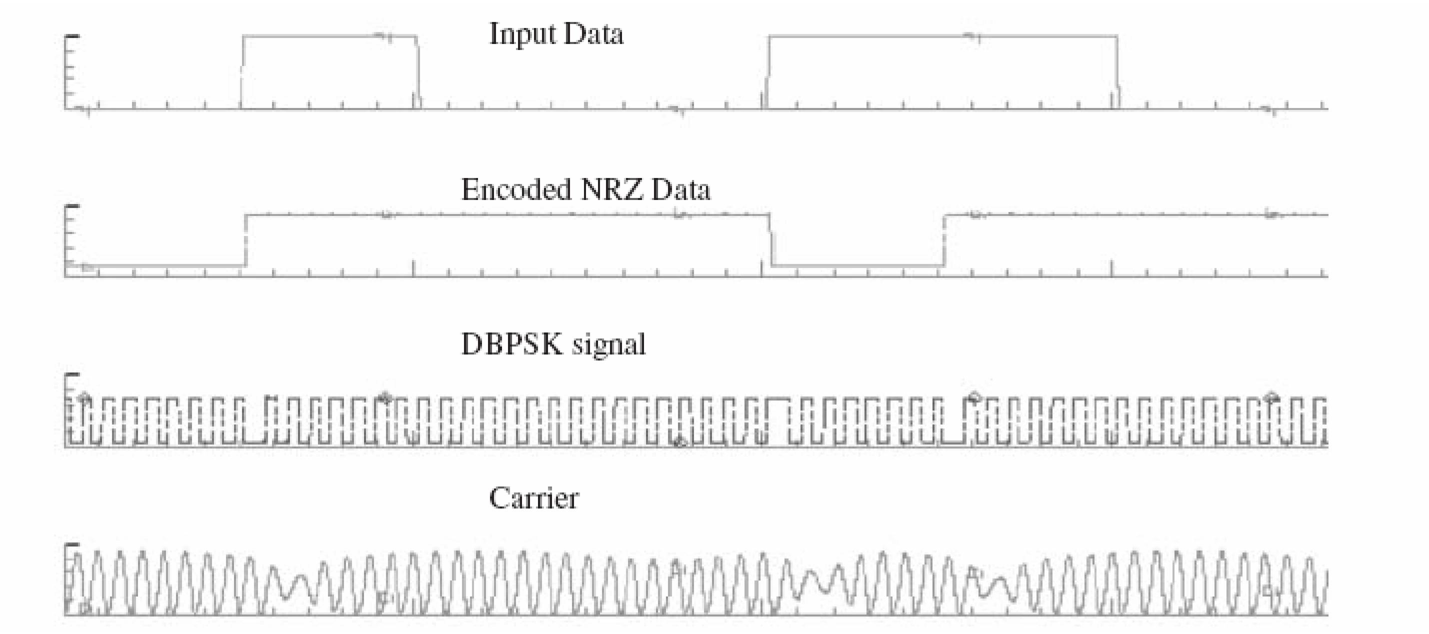


Differential binary phase shift keying

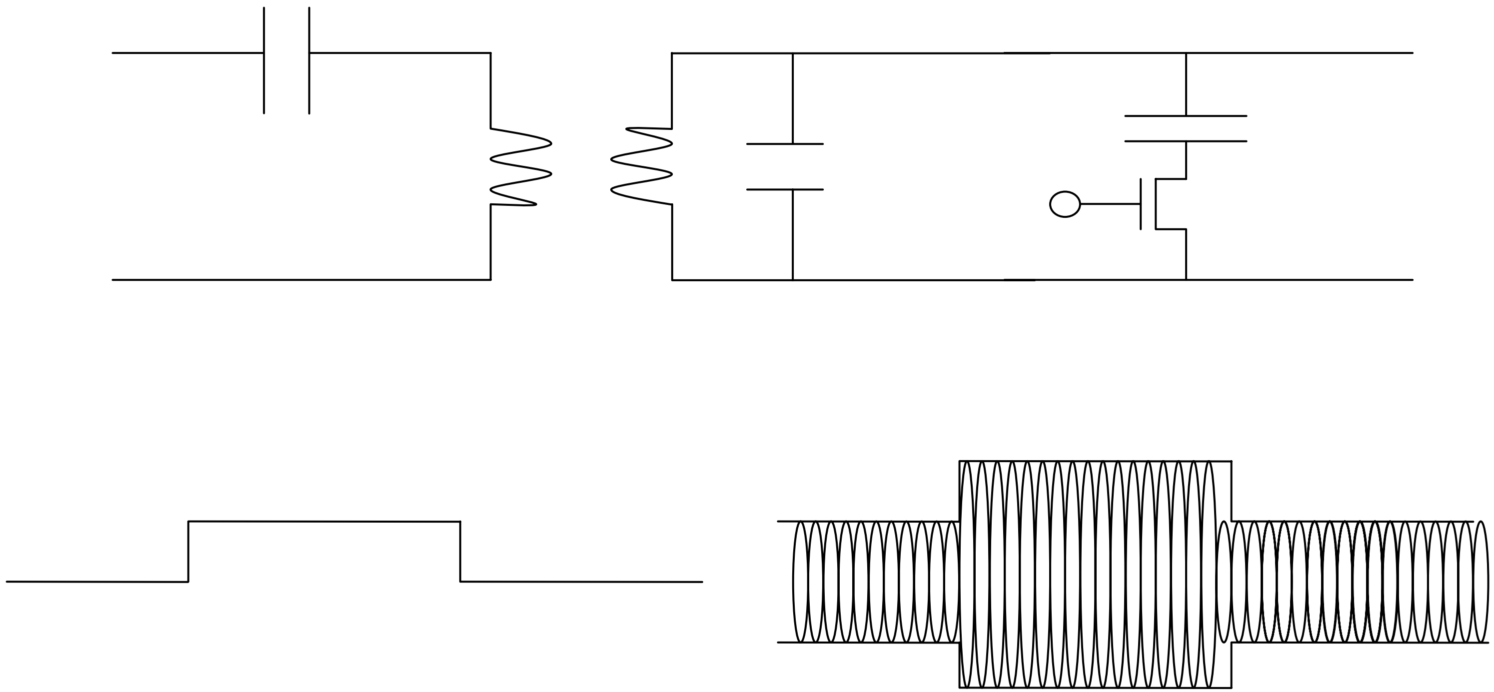
- Limitation of current technologies for the telemetry
  - Too slow to transmit enough data for high resolution.(1.5-2Mbps needed)
- This approach achieves higher data rates.
  - By allocation different freq for the power and forward telemetry data carriers.
  - The Carrier freq is 16MHz.

Forward Encoding Method 2

- DBPSK

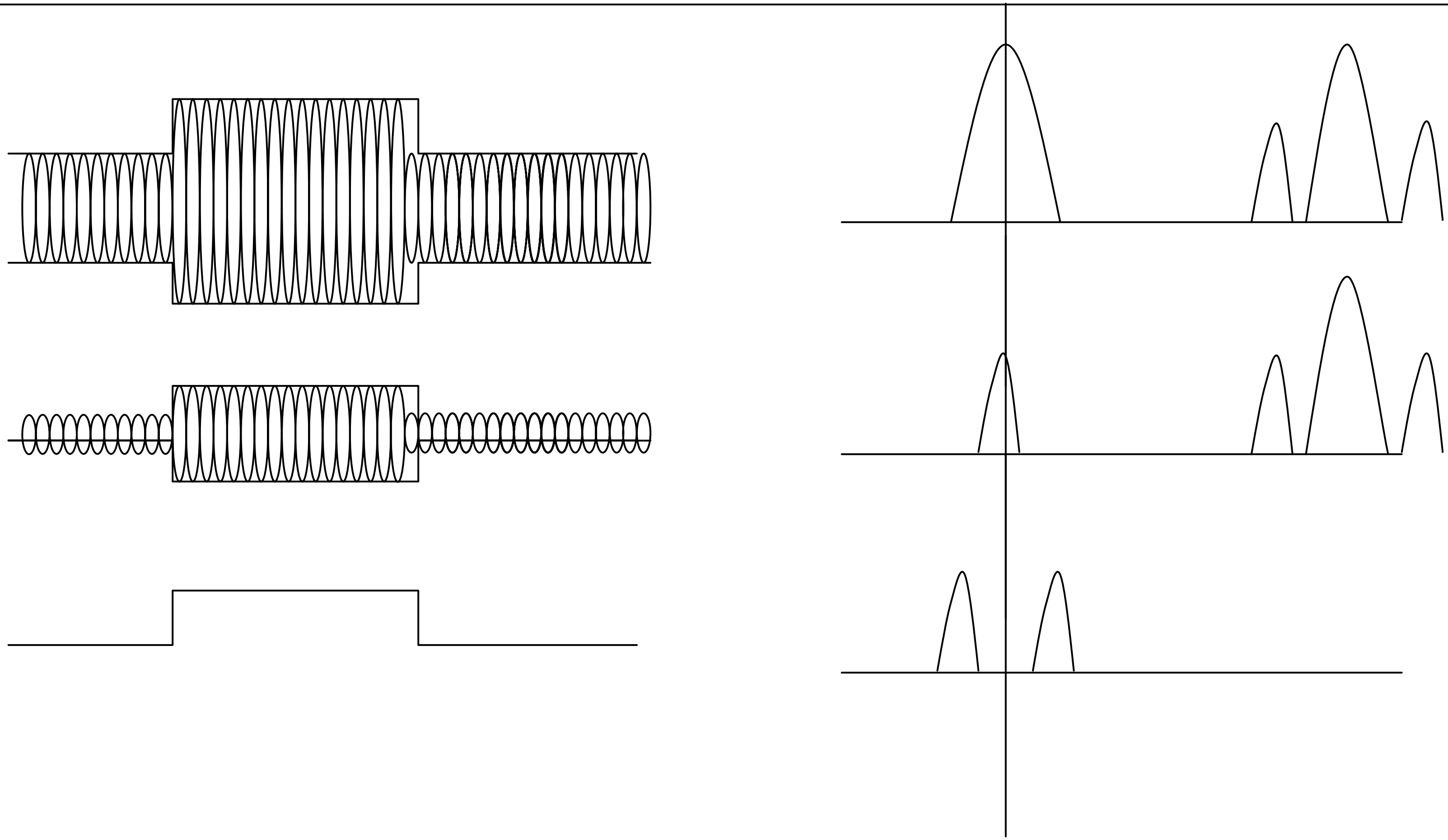


Modulation of Back telemetry



C2’ = C2+(Ca//Cmos)

Demodulation of Back telemetry



Power transmission

- Vs power
- Resonant freq matching (Class E amp, Inner, Outside circuit)
- Number 0f Turn
- Condition
  - coil characteristic (material, parasitic R,C)
  - Skin

Retina-3.55 circuits

Technology	1.2-μm CMOS
Die size	5.5 mm x 5.25 mm
Circuit area	4.7 mm x 4.6 mm
Number of current generators	60
Number of stimulation outputs	60
Data packet size	1024
Timing resolution (edge placement)	4 clock cycles (1/256 of frame time)
Supply voltage	+7 V, -7 V
Amplitude resolution	4 bits
Full-scale settings	200 μA, 400 μA, 600 μA
Anodic/cathodic matching	7.24%
Supply sensitivity	16 μA/V
Power consumption (600 μA, 1 ms pulse widths, 60 Hz)	42 mW

Retina-3.55 photograph

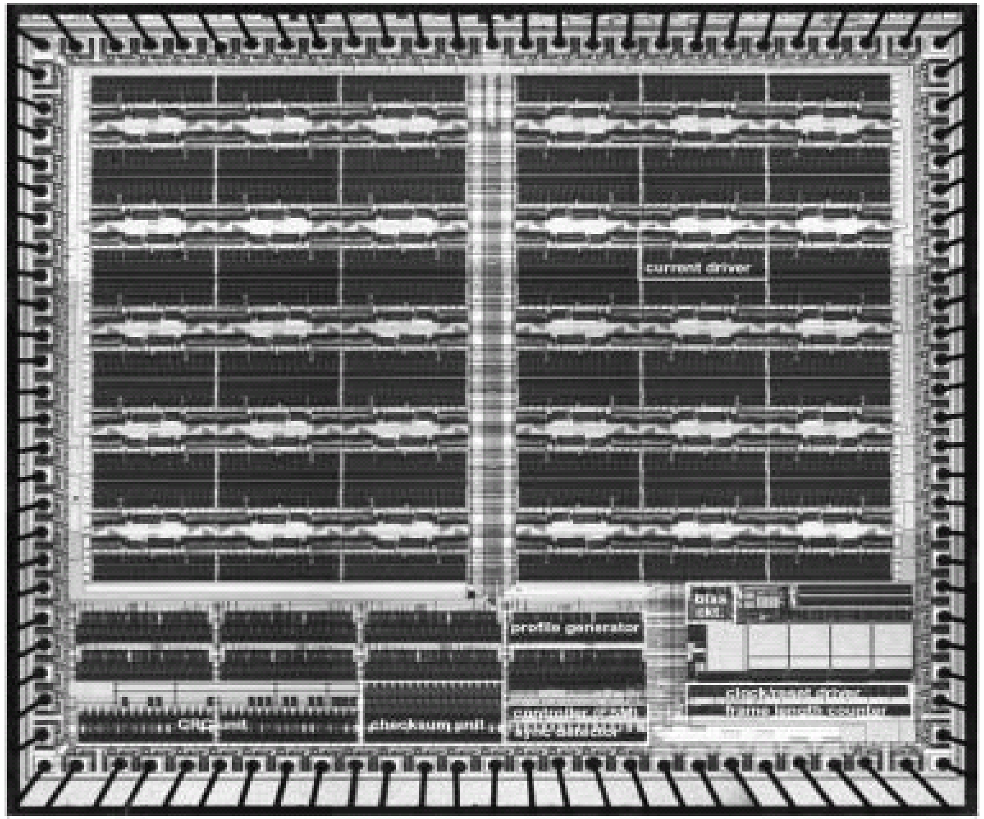


FIG. 8. Retina-3.55 photograph (4.6 mm × 4.7 mm).

Electronic Visual Prosthesis
Part 2

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- Introduction
- Specification of previous retinal Ics
- Retin-3.55
- Design of next generation retinal Ics
- Packaging issue
- Intraocular electromagnetic and thermal radiation
- Fabrication result
- Conclusion

Introduction

- Epiretinal approach for Retinitis pigmentosa (RP) and age-macular degeneration (AMD) patients
- Two parts system(external unit and internal unit)
- Stimulator chip with a small area and low power consumption

Specification of previous retinal ICs

Retinal chip	Salient features
Retina-1	5x5 photo sensor array and current drivers: 2.0um CMOS technology
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Retina-3.55 circuits (1)

❖ Digital circuit feature

- Data input error detection
- Profile generation
- Data distribution to analog circuits
- Control logic circuits

Retina-3.55 circuits (2)

❖ Communication protocol

- 1024-bits for one command
- 16-bit synchronization word
- Configuration packet
- 16-bit Data packet per one channel

Retina-3.55 circuits (3)

❖ Pulse profile

- 4-bits resolution
- 8-grobal programmable pulse timing references

Retina-3.55 circuits (4)

❖ Error detection

- Due to telemetry link bit error
- 32-bit CRC
- 16-bit checksum error
- Remove packet or frame

Chip design for next generation retinal Ics(1)

❖ requirment

- 32 x 32 (1000) stimulus matrix for face recognition
- Low power consumption
- Reliability of long life time

- TSMC 0.35 um technology
- 1: 8 output demultiplexing
- Single DAC
- Reducing headroom of current mirror

Chip design for next generation retinal Ics(2)

❖ TCMS 0.35 um technology via AMI 1.2 um

- 1/3 size achieve 1/9 area
- 4 metal layers compared to 2 metal layers

  → higher circuit density

- Not much effective for analog circuit

Chip design for next generation retinal Ics(3)

❖ 1:8 output demultipexing

- 1 driver and drive 8 pixels
- Each pixel is activated for 2 ms in a period of 16.67 ms
- 60 frames per second

Chip design for next generation retinal Ics(4)

❖ Single DAC

- Reduces area
- Reduces any current amplitude mismatch

Chip design for next generation retinal Ics(5)

❖ Headroom reducing(1)

- Reducing the headroom required by the current mirror can significantly decrease the power dissipated in the output driver stage
- Using active feedback current mirror

  → voltage drop reach up to 12.5 V

  TSMC 0.35 gate oxide breakdown at 5 V
- High voltage transistors can help it

Chip design for next generation retinal Ics(6)

❖ Headroom reducing(2)

- High voltage transistors problem
  - Matching of the low voltage and high voltage transistors
  - Large size of a high voltage device
  - Large series resistance at the drain region
- Use Low voltage transistors and dynamically biasing the device

Packaging issue

❖ Hermetic seal

- Biological fluid in the eye
- Electrical isolation for the tissue around the chip

Intraocular electromagnetic and thermal radiation

❖ heating effect

- The implant can change the steady state temperature of the eye
- Heat from absorption of electromagnetic radiation in tissues
- Heat from implanted chip
- Simulation to verify the safety of the effect

Fabricated result

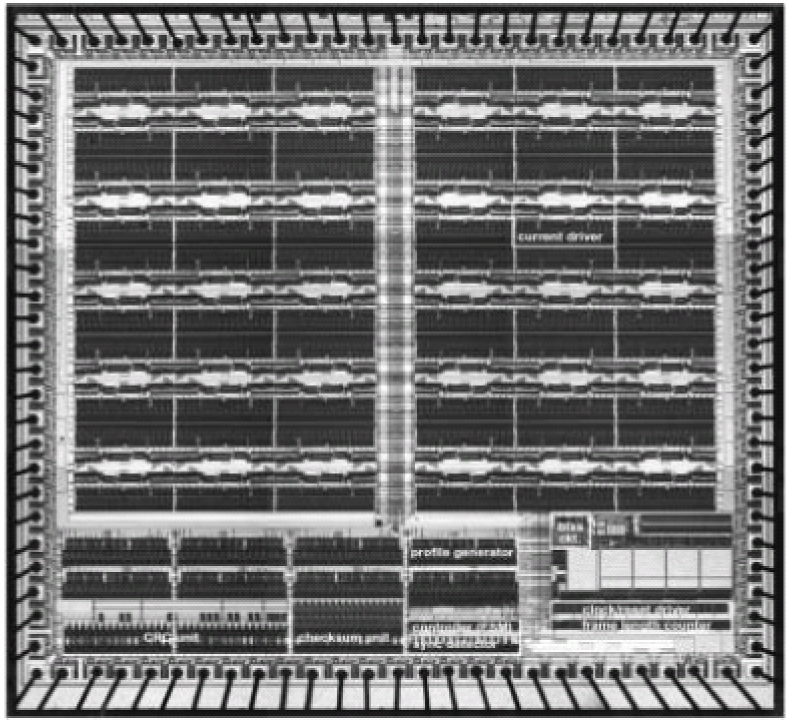
❖ Telemetry unit

- Power supply rails of 7/14 V
- 25-250 kbps

Fabricated result

❖ Stimulus chip

- Retina-3.55
- Size of 4.6 X 4.7 mm^2



Conclusion

- Stimulus circuit for the retinal prosthesis
- Can be used to other implant system
- Study of nature require many fields such as biomedicine, chemistry, electronics and material science and so on