BIONIC EYE

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HUMAN EYE STRUCTURE
EYE DEFECTS

- Type 1: By Damage of Retinal Cells
- Type 2: By Damage of Ganglion Cells
- Type 3: By Damage of the optic nerve

Bionic eye restores the vision lost due to damage of Retinal cells
Bionic Eye: Two Approaches

- **MARC – Multiple Unit Artificial Retina Chipset**
  - The images are captured by an external camera.
  - Processed and then transmitted to an implant on the retina.
  - This in-turn will transmit it to the ganglion cells and then to the optic nerve.

- **Silicon Retina**
  - A retina is simulated on silicon.
  - The basic blueprint for this is the human eye itself.
  - The Silicon retina is implanted in the eye.
  - No external devices required.
Multiple Unit Artificial Retina Chipset (MARC) – The Concept
MARC System Functionality
Extra-Ocular CMOS Camera & Video Processing

Video Processing
- Implemented using SRAM Frame buffers, ADC & a FPGA/CPLD
- Reconfigurable FPGA's allow flexibility for various Image Processing Algorithms including Artificial Neural Networks
ASK-PWM Encoding

Alternate Mark Inversion

- Each pulse encodes 1 bit of data
- 0’s represented by 50% duty cycle pulses
- 1’s represented by pulses with alternating larger or smaller duty cycles (75% & 25% respectively) symmetric around 50%
Class-E Power Amplifier

- The class E amplifier is a highly efficient switching power amplifier, typically used at such high frequencies that the switching time becomes comparable to the duty time.

- The whole circuit performs a damped oscillation.

- With load, frequency, and duty cycle (0.5) as given parameters and the constraint that the voltage is not only restored, but peaks at the original voltage, the four parameters (L, L₀, C, C₀) are determined.
RF Telemetry

- An Inductive Link consists of 2 resonant circuits.
- Mutual Inductance $M$ plays a vital role, Maximizing it is very important.
- As the MARC transmits information via AM/ASK, fluctuations in the coupling constant could potentially be perceived as information by the processing chips.
- Primary coil is driven with 0.5-10MHz signal for Power accompanied by a 10KHz ASK signal which provides data.
- It is suitably recovered at the receiving end.
Data, Clock & Power Recovery

Data & Clock Recovery

- The low frequency data signal is obtained by a Low Pass filtering.
- The first RF signal conveys the configuration data which sets the pulse width, height and period. Then the actual image is transmitted.
- ASK demodulator obtains the PWM scheme.
- Delay Locked Loop (DLL) deciphers the PWM wave to obtain the Data transmitted.
- Clock is defined as the rising edge of the pulse & no explicit clock recovery circuits are required.

Power Recovery

- The high frequency RF carrier envelope is obtained by filtering the output of receiver coil.
- The sinusoidal signal is then amplified to suitable levels and then rectified.
- Rectification provides the required DC voltage power.
Current Controller and Stimulator

- 20 controlled variable current (CVCS) sources are designed for retinal simulation
- Each receive clocking & data info from deciphered PWM wave
- Each CVCS is connected to 5 electrodes through a DEMUX
- Each current source provides sixteen level (4 bit) linear gray-scale stimulus
- Thus each of the 100 electrodes are exited by different currents which form the desired image pattern

Figure 9: MARC3 Architecture
Typical Image Formation

Enlarged area

Video Camera

Implant

Laser or RF

Eyeball

Retina

Area of photoreceptors destroyed by disease

Electrodes

Ganglion Cells

Photo-receptors
MARC-3 Chips

The Electrode Array

Photograph of MARC-3 Chip
Important Aspects

Field of View

- More the number of Ganglion cells stimulated, more is the field of view.
- Thus large electrodes and the area becomes a trade-off.

Changing Scene and Real-time vision

- The whole process must happen extremely fast so that patients see in real time.
- This is important as any noticeable lag could stimulate the "vestibular-ocular reflex", making people feel dizzy and sick.
Silicon Retina: The Second Approach

- A silicon chip that faithfully mimics the neural circuitry of a real retina could lead to better bionic eyes for those with vision loss, researchers claim.

- The circuit is built with the mammalian retina as its blueprint. The chip contains light sensors and circuitry that functions in much the same way as nerves in a real retina – they automatically filter the mass of visual data collected by the eye to leave only what the brain uses to build a picture of the world.

- To make the chip, a model of how light-sensitive neurons and other nerve cells in the retina connect to process light is created. A silicon version using manufacturing techniques already employed in the computer chip industry.
Changing Scene

- The mammalian brain only receives new information from the eyes when something in a scene changes.

- This cuts down on the volume of information sent to the brain but is enough for it to work out what is happening in the world.

- The retina chip performs in the same way.

- As well as having the potential to help humans with damaged vision, future versions of the retina chip could help robots too!
The Images

- The top image shows the raw output of the retina chip.

- The middle one a picture processed from it.

- The third shows how a moving face would appear.
Event-based Temporal Contrast Silicon Retina

- Frames have big disadvantages under real-world conditions for dynamic vision -- small dynamic range and fixed uniform sample rate.

- All the pixels from every frame must be processed to extract meaning.

- Biology does it differently: retinas extensively use local gain control, they reduce redundancy dramatically, and ganglion cells only spike when they have something to say.

- The retina chip pixels respond with precisely-timed events to temporal contrast.
How it Works?

- Movement of the scene or of an object with constant reflectance and illumination causes relative intensity change.

- Thus the pixels are intrinsically invariant to scene illumination and directly encode scene reflectance change.

- The events are output asynchronously on an Address-Event bus, so they have much higher timing precision than the frame rate of a frame-based imager.

- Because the pixels locally respond to relative change of intensity, the device has a large intra-scene dynamic range.
Pixel Architecture

- The pixel is beautifully drawn by Patrick to use quad mirror symmetry to isolate the analog and digital parts.

- Most of the pixel area is capacitance.

- The chip includes a fully programmable bias current generator that makes the chip's operation largely independent of temperature and process variations.
Pixel Functionality

- The pixel uses a continuous-time front end photoreceptor.
- This is followed by a precision self-timed switched-capacitor differentiator.
- The most novel aspects of this pixel are the capability to self-bias the photoreceptor, and the idea of self-timing the switch-cap differentiation.
- This data converter pixel does a data-driven conversion (like biology, but very different than the usual ADC architecture).
- Various Interfaces are provided for testing.
Thank You!