VLSI CONTRAST MODULE FOR ROBOTIC VISION

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Abstract

Design of B, H, and R, neural-type circuit modules is presented using CMOS devices. These modules emulate the behaviour of biological cels associated with the human retina. The interconnection of these three modules to produce the contrast type response has been experimentally studied on lumped electronic circuits. The VLSI circuit using CMOS devices for the three modules has been designed on the CALMA Graphics Computer, and the VLSI layout for the contrast module is presented.

I. Introduction

At the present time, robotic systems are mainly composed of mechanical functions connected for the purpose of achieving a specific form of automation. As in the human body, the robotic processing system is the controlling system for visual and sensory functions. The objective of neural-type robotic vision is to obtain a vision system, mimicking as much as possible the mammalian visual system as we know it.

The retina is a network of nerve cells which are 'hard wired' according to a particular organizing scheme. The neuron networks of the vertebrate retina have been investigated by physiologists by stimulating the retina with various light patterns and observing the corresponding output activity of single retinal cells using microelectrodes inserted in these cells [1]. The (photo) receptor cells in the retina, called rods and cones, sense the information in the visual field and send this information as coded signals to ganglion cells through Horizontal, Amacrine and Bipolar cells [2]. The axons of ganglion cells exit from the eye and form the optic nerve. The fibers of the optic nerve synapse in the lateral geniculate nucleus in the thalamus. Axons of neurons in the lateral geniculate nucleus relay the information from each eye to the primary visual cortex.

In [3] we have set up a system of neural-type electronic cells to perform these functions, these cells being bipolar, horizontal, and receptor ones based upon similar cells in the vertibrate retina. In this paper we give initial results on the IC designs using CMOS devices.

II. Neural type Modules

Based upon the properties of biological cells associated with the retina, the follwoing modules have been introduced [3].

B-Module: This circuit generates slow, graded (single output) responses to (multiple) inputs coming from Receptor (R) modules and a (single) Horizontal (H) module. These inputs are summed to give the B-module output. This summation is non-linear but monotonic, and shows quick saturation when sufficient inputs are excited. There are two types for negative (B^- module) and positive (B^+ module) going pulse inputs from the H-module. This leads to two correspondingly different polarity types for the output signal which is accomplished through MOS invertors.

B-modules behave like bipolar cells in the retina system, for which there are those that are stimulated to give excitatory outputs and those that are stimulated to give inhibitory outputs.

The circuit diagram of the B-module is shown in Fig. 1(a). V_1, V_2 ··· V_n are the multiple inputs and V_H is from the output of the H-module. SIL 4007 AE COMOS Integrated Circuit chips have been used for experimentally studying the behaviour of this circuit. (Supply voltage V_{DD} = 12 Volts and R_1 = 5·6K). A CRO picture of the response of a B-module is shown in Fig. 1 (b), for the pulse type of input. Horizontal scale: 5 MSEC/ division, Vertical scale: 5 volt/div. As long as the input level is below threshold (2·4 volts), the output of the B-module remains high. When the input level crosses the threshold, the output shows dips with quick saturation.

H-Module: These circuits take their (multiple) inputs from R-modules and generate slow, graded responses, there being simultaneous positive and negative outputs. Similar to the B-module, the inputs are summed nonlinearly, monotonically and with quick saturation when sufficient receptor inputs are excited. This phenomenon can be emulated using CMOS devices operating in their quadratic region. The inputs are summed quadratically far above the threshold values.

H-modules are analogous to biological cells that are structurally positioned such as to allow for horizontal spread of signals, thus justifying their name-Horizontal cells.

The circuit diagram of an H-module is shown in Fig. 2(a). V_1, V_2 ... V_n are multiple inputs of the H module which gets signals from receptor (R) modules. SIL 4007 AE CMOS Integrated Circuit chips have been used for experimentally studying the behaviour of this circuit. (Supply voltage V_{DD} = 12 volts, R_1 = R_2 = 5·6K). An oscilloscope trace of the response of an H-module is shown in Fig. 2 (b), for the pulse type of input signal. Horizontal scale: 5 MSEC/div, Vertical scale: 5 Volt/div. Once the input level crosses the threshold (2·4 volt) voltage, the output shows the quadratic summation and, therefore, amplification of the multiple inputs.

R-Module: This circuit converts a single external pulse signal (of varying heights) to two (classes of) positive going output voltages on a logarithmic scale. These outputs of R-modules are connected to H-modules and B-modules. R-modules behave like the receptor cells of the retina.

Figure 3 (a) shows the circuit for the R-module. This circuit basically works as an operational amplifier. The supply voltage V_{DD} can be +12 volts (single sided). R_2 should be 100K to 1MΩ for setting reference bias [4]. R_1 is input resistance, 1K. The frequency compensating capacitance C is about 5 PF. The diode in the feedback loop causes this circuit to behave as a logarithmic amplifier. For experimentation, the integrated circuit CA 3130 S chip (by RCA) has been used [5] to build a similar circuit as that of the R-module, which gives logarithmic type dependence of the output voltage on the input pulse amplitude.

For a pulse type of input, a CRO picture of the response of an R-module is shown in Fig. 3 (b). Horizontal Scale: 50 μSEC/div, Vertical Scale:10 volt/div. With increasing height of the input pulse, the output amplitude rises but with slower and slower rate.

III. Interconnections

The connection of the above mentioned three modules to form the contrast-type circuit is shown in Fig. 4 (a). The name is derived from the functions perceived for the analogous interconnections of biological cells in the retina.

A CRO picture of the response of the contrast-type interconnection is shown in Fig. 4(b). For pulse type input, the output of the H-module is shown in the top trace and the output of the B-module in contrast-type connection is shown in the bottom trace. Horizontal scale: 50 μsec/div, Vertical Scale: 5 volt/div. The amplitude of both outputs changes corresponding to input pulse voltage level.

IV. VLSI Circuit description:

CMOS has certain advantages in terms of less power dissipation, higher noise immunity and wide supply voltage range. The CMOS VLSI circuit layout for B-module, H-module, R-module, and contrast type interconnection module are shown in Fig. 5(a) to 5(d). Figure 5 (e) shows a number of contrast modules in parallel, to represent a large collection of biological cells in the retina. The design rules for CMOS Integrated Circuits in VLSI are described in detail in [6]. In design, dimensions are given in units of the scaling parameter "lambda", which is equal to half the minimum feature size. For this CMOS design, lambda equals to 2.5 microns. CMOS has both n and p type diffusions. P channel transistors are inside a P^+ region but outside P wells whereas n-channel transistors are outside the P^+ region but inside the P well. There must be certain minimum clearance, (specified by a certain number of lambda), between two strips of the same type on the same layer or of different type on different layers. For example, between two metal strips there must be a minimum of 3 lambda separation to avoid short circuits. Also a diffusion strip must have a width of at least 2 lambda. A resistor is realized by a depletion mode transistor with its gate tied to its source. The channel width and length determines the value of resistance. The capacitance between diffusion layer and metal layer is utilized to achieve the required capacitance [7], [8]. When a required amount of diffusion area is overlapped by a metal plate, a capacitor is formed which has value proportional to the area. The various layers in the CMOS fabrication process are a represented on the computer by different colors according to a conventional color code.

The CALMA computer has been used to design the above mentioned VLSI circuit-layouts. CALMA, manufactured by General Electric, is a powerful color Graphics Computer used for Computer Aided Design (CAD). Resoulution details up to 1 micron are possible. Huge and complicated circuit layouts for chips can be designed with ease using various functions on the CALMA System. Besides a 'design rule check' software package allows the user to check for errors in design.

V. Conclusion

The B, H, and R-modules connected in certain organized fashion, form the contrast-type interconnection. The threshold characteristic of the MOS devices has been utilized to realize the desired response. The experiments performed on lumped and integrated circuits show the response of these modules which have been designed to emulate biological cells in the retina.

The contrast function module models the point-by-point transformation from light intensities to their neural representation. Because of the availability of Very Large Scale Integrated (VLSI) circuits, it is possible to have a number of pulse processing circuits grouped together to emulate the large collection of different types of biological cells, in the vertebrate retina. This will lead us to realize vision system for robots.

VI. References

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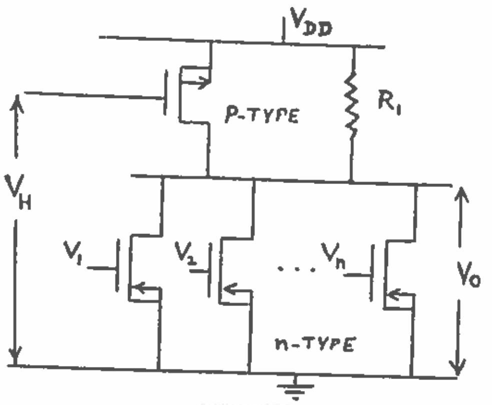
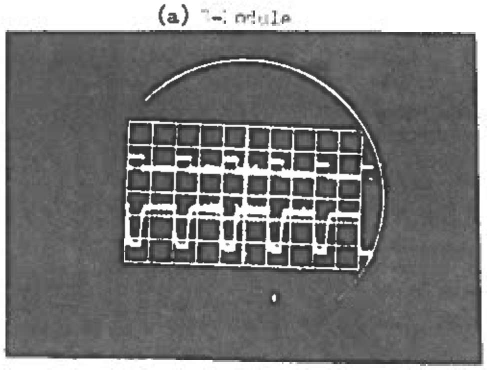
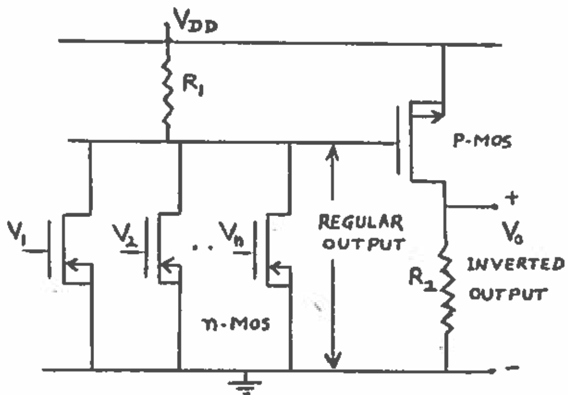


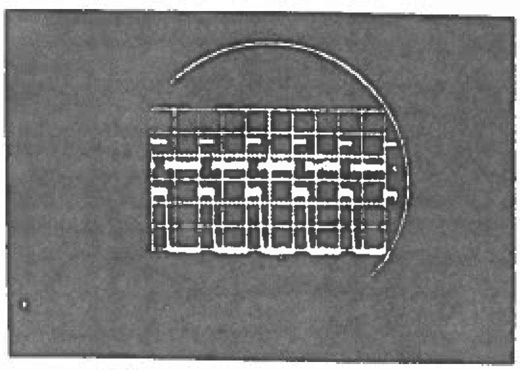
(a) [illegible]-Module



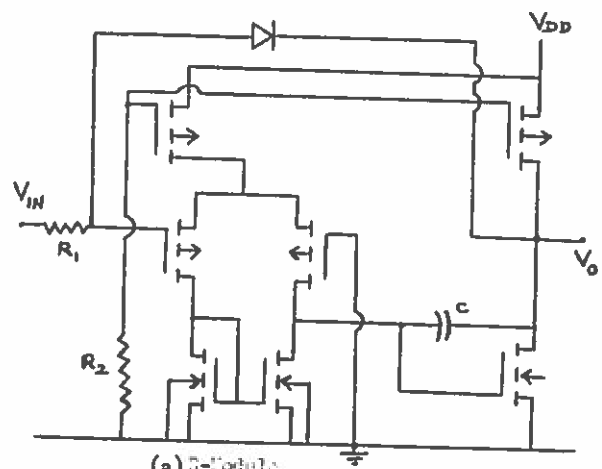
(b) Response of [illegible]-Module
Figure 1



(a) [illegible]-Module



(b) Response of [illegible]-Module
Figure 2



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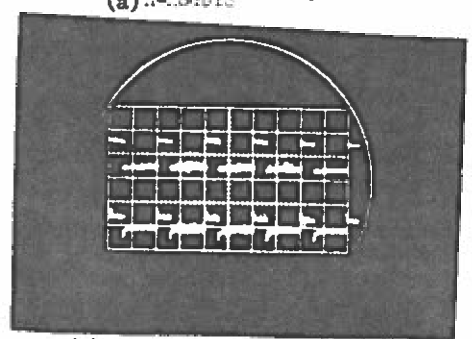
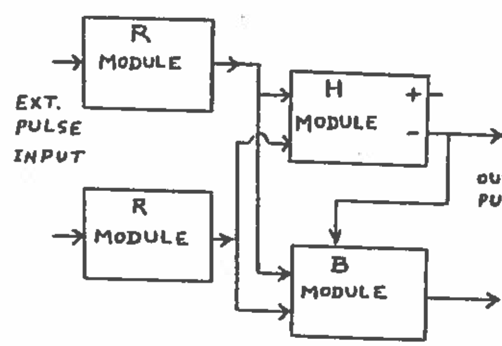
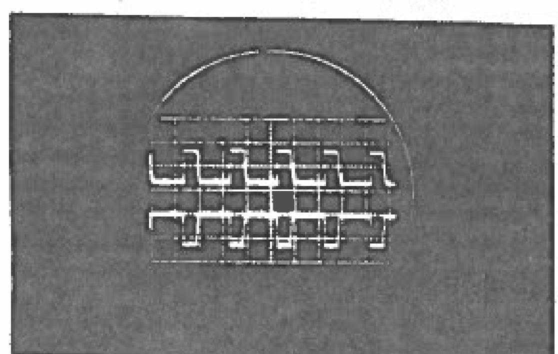


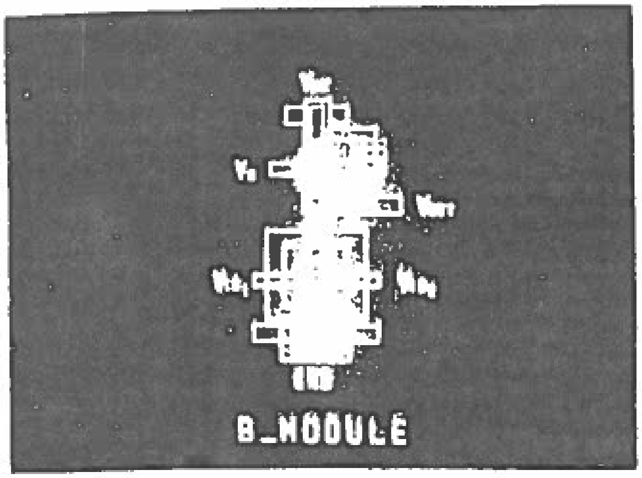
(b) Response of [illegible]-Module
Figure 3



(a) Contrast Type Interconnection



(b) Response of Contrast Type Interconnection
Figure 4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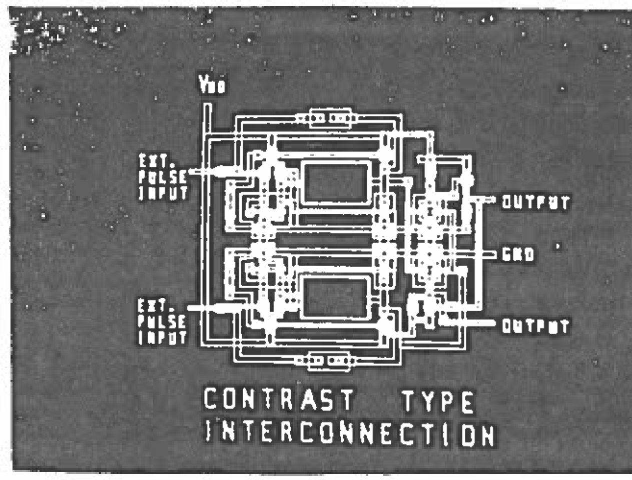
B_MODULE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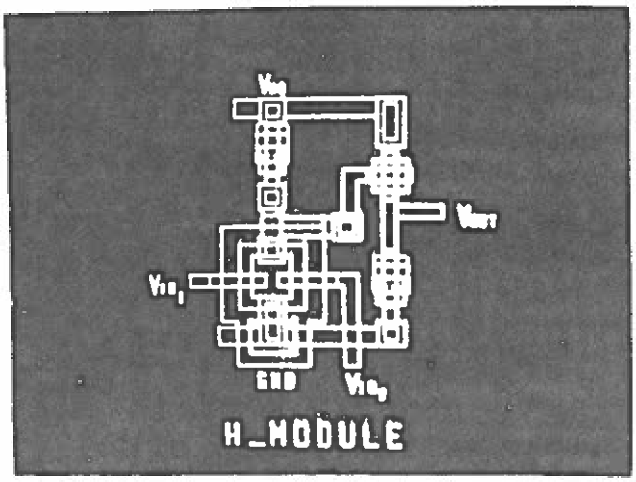
INPUT
OUTPUT
GND
EXT.
PULSE
INPUT
OUTPUT
CONTRAST TYPE
INTERCONNECTION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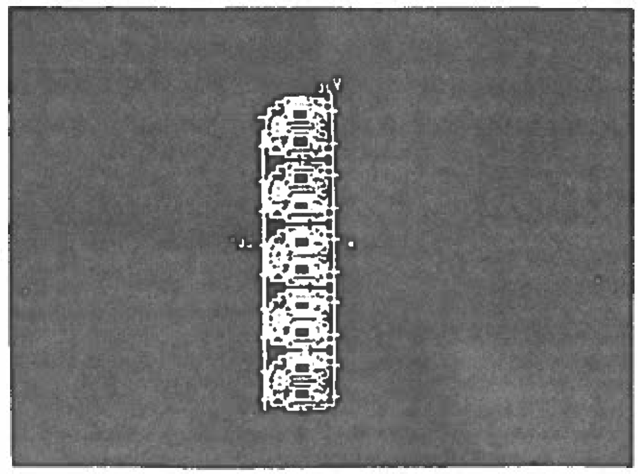

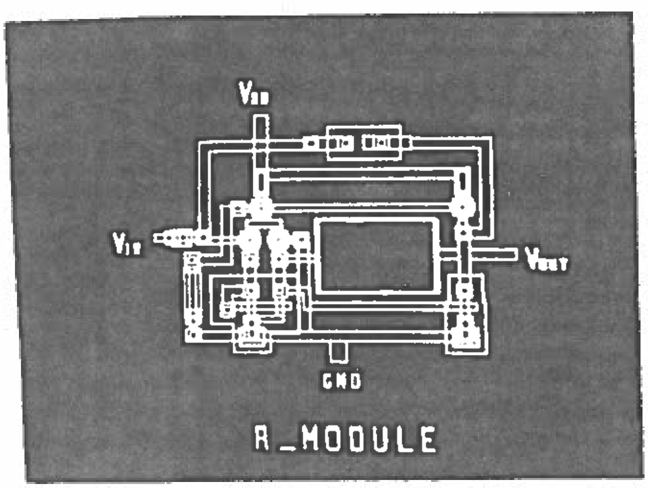
GND
R_MODULE

R. Newcomb

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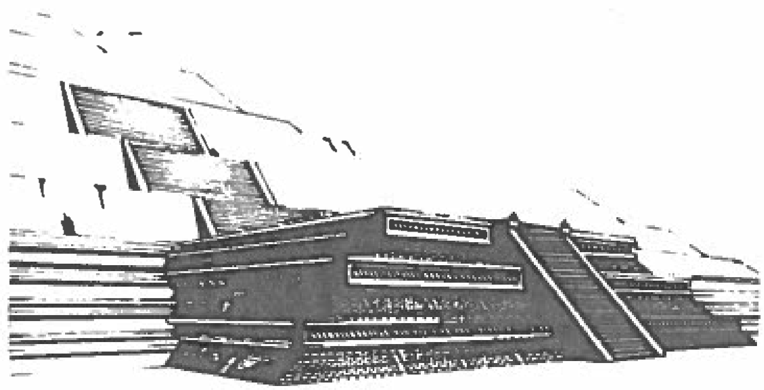

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