Antiques from the Innovations Attic

Organizer: *Trudy Stetzler, Houston, Texas*
Moderators: *Anantha Chandrakasan, Massachusetts Institute of Technology, Cambridge, and Bram Nauta, University of Twente, Enschede, The Netherlands*

Rousing nostalgia for the IC yesteryear, panel organizers Trudy Stetzler, Bram Nauta, and Anantha Chandrakasan said in their Conference Digest overview "When you clean up your attic you may find things that you have totally forgotten about: old toys you used to play with, old books with lost stories. And then you think back to those past days and view them in the context of today's busy life, and sometimes find new uses for forgotten items. This panel does a similar thing."

The six experts they invited from academia and industry "to dig into their memories and find lost treasures in circuit design" were asked specifically "to reveal circuits and concepts that they feel are the most interesting, intriguing, and underappreciated innovations from the past" and to "explain why the concept is significant today and should be pulled from the innovation attic."

Their confab, which drew an estimated 2,000 people on Monday evening, offered many notable remembrances:

Eric Vittoz highlighted "current-mode analog circuits in weak conversion" as those seldom used in the past because of their poor precision due to threshold mismatch. But these circuits, he said, may regain interest in deep submicron processes where larger-than-minimum devices could be used to reduce threshold mismatch.

Coincidentally, Rinaldo Castello also highlighted current-based processing as the antique from the past with renewed appearance as what he termed "pipe" processing and "pipe" filters.

From left: Thomas Lee, Nicky Lu, Rinaldo Castello, Yoshiaki Hagihara, Eric Vittoz, Robert Brodersen, and panel moderators Anantha Chandrakasan and Bram Nauta.

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Nicky Lu, flanked by intently listening Tom Lee and Rinaldo Castello.

Yoshi Hagihara, Eric Vittoz and Bob Brodersen.

Robert Brodersen offered time-domain processing as his "basic attic idea" and how this could be used to attack the most important problems of radio design. He pointed to impulse radio and active cancellation as "two time-domain projects from the attic."

Nicky Lu picked core memory as an antique that is now resurfacing as spin-torque transfer magnetoresistive random-access memory (STT-MRAM).

Yoshiaki Hagihara shared his memories of Richard Feynman, his mentor and educator at Caltech, and how he learned from him that control of electrons is at the heart of all electronic devices. As an example from his attic, he pointed to the old p-n-p-n junctions that are now incorporated in modern-day image sensors.

The last speaker of the session, Thomas Lee, focused on the mysteries and misunderstandings surrounding the linear time-varying (LTV) circuits where the Laplace transform in its simple form cannot be used for analysis. Examples from his attic were super-regenerative amplifiers and parametric systems.

A full-length accounting will appear in this magazine in the Summer 2013 issue.

—Ali Sheikholeslami
ISSCC Educational Events Chair

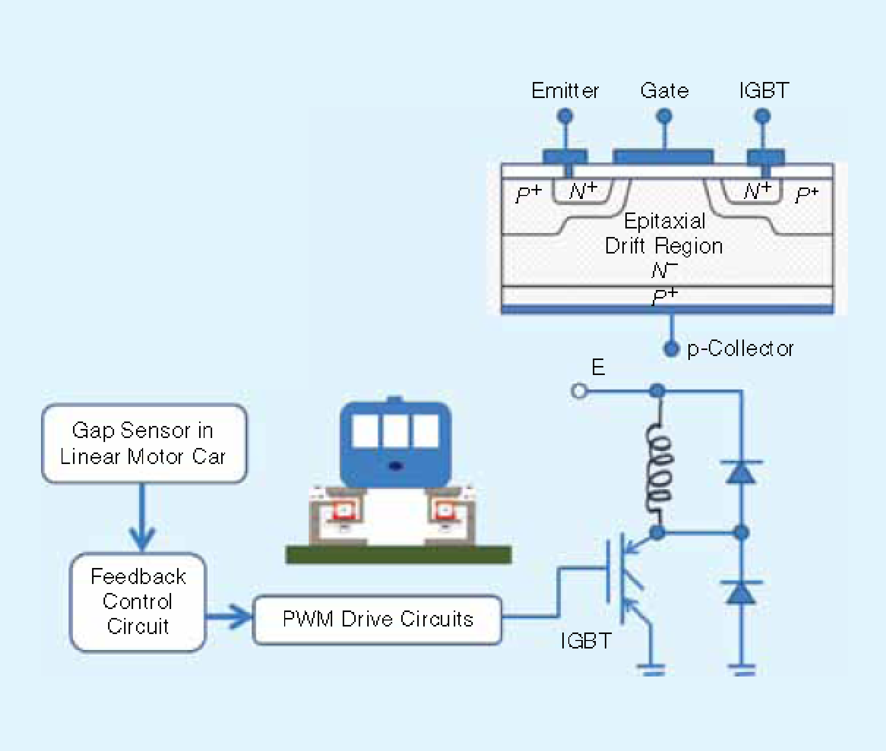

FIGURE 9: The p-n-p-n switch diode for a modern linear motor car.

Yoshiaki Higihara: The p-n-p-n Diode in Future Linear Motor Cars and in Modern Imagers

John Louis Moll (1921–2011) was studying a p-n-p-n diode switch in his Ph.D. dissertation work when the first ISSCC was held in 1954. In a normal operation mode, this device works as a thyristor, which can drive a large current and is the key device structure of an IGBT applied for a linear motor car of the future (see Figure 9). In a dynamic operation mode, this device may work as a simple p-n-p-n dynamic capacitance that can detect and store one single electron, which is a key device structure of the modern image sensor (see Figure 10).

I recall, when I was taking his physics course at Caltech, that Feynman once said that an electron is always free, moving around rapidly in free space, even in solid, and it never stops. It is very hard to catch an electron because we do not know exactly where it is. Our civilization today is based on a technology that controls electrons, down to a single one.

Imagine a photon incident to a bipolar transistor base region. The photon energy creates an electron-hole pair. And the photo-electron can be stored in the base region as one single majority carrier. That is, a bipolar transistor can also function as a photon detector and/or a storage container. I thought that a room in a hotel must be empty and clean before the first hotel guest arrives. So must be this transistor base region empty and clean with no guest electrons at the beginning. This transistor in a dynamic p-n-p capacitor mode is useful since it can capture, confine, and control one single electron. But as a student, I did not know yet how to move that single photoelectron sitting in the base region to the outside world so that we can make use of it as a signal. I had no way yet to know whether the hotel guest has arrived and is resting in the hotel room or not. We had no way yet to ask the hotel guest to come up to the hotel lobby to meet me. I had to wait a few more years (until 1970 in my senior year in college) to find the answer. We all know now it is the CCD structure that can store and transfer one single electron. With a precharge reset set gate and a source-follower circuit, a scheme invented by Walter Kosonocky. We could finally meet our hotel guest at the hotel lobby.

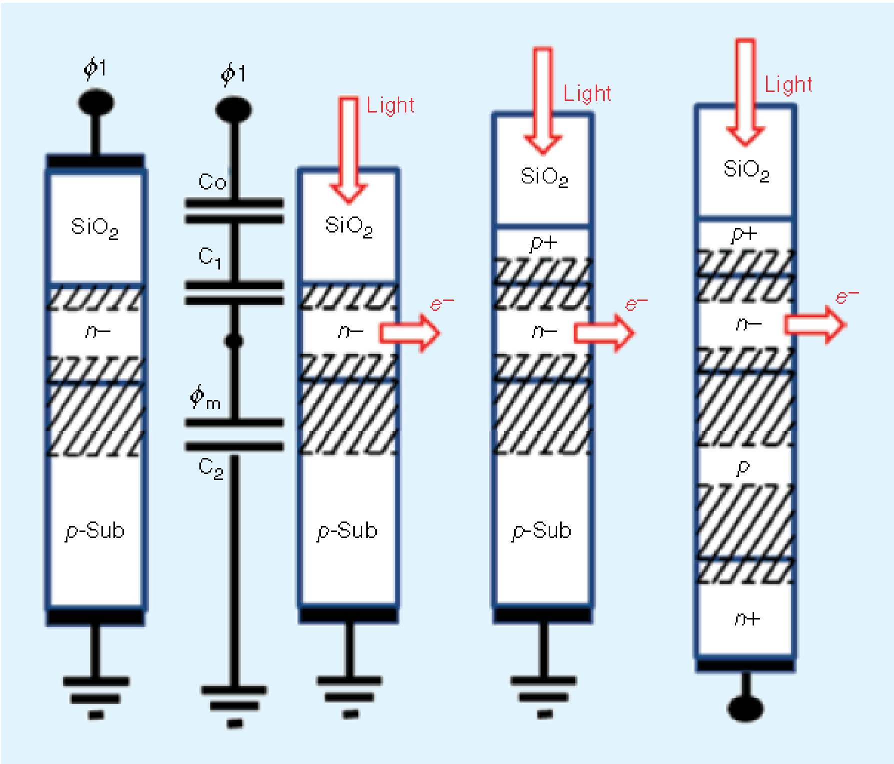

FIGURE 10: From CCD to the dynamic p-n-p-n diode capacitors.

http://isscc.org/

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Far East Committee Chair

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2008	Y. Hagihara	Sony	2009	W. Bowhill	Intel	2010	A. Theuwissen	Harvest Imaging/ Delft Univ
2011	W. Gass	Texas Instruments	2012	H. Hidaka	Renesas Electronics	2013	B. Nauta	Univ of Twente

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1989-1990	T. Sudo	NTT	1991-1992	T. Nakano	Mitsubishi	1993-1994	H. Ishikawa	Fujitsu
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ISSCC2013 San Francisco , Feb 18 2013


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60 Years of (Em)Powering the Future
SSCS
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Plenary Talks (Monday, February 18)
Lisa Su
Senior Vice President and General Manager, AMD
Heterogeneous Computing - Driving Growth and Innovation in the Semiconductor Market
Martin van den Brink
Executive Vice President and Chief Product & Technology Officer, ASML
Next Generation Lithography : Progress and Outlook
Yoshiyuki Miyabe
Managing Director and CTO, Panasonic
Smart Life Solutions from Home to Cities
Carver Mead
Professor Emeritus, Caltech
The Evolution of Technology
60TH Anniversary Distinguished Evening Panel
(Monday, February 18) "Antiques from the Innovations Attic"
Robert Brodersen
Professor Emeritus
University of California Berkeley
Rinaldo Castello
Professor
University of Pavia
Yoshiaki Daimon Hagihara
Professor
Sojo-university
Thomas Lee
Director
Microsystems Technology Office, DARPA
Nicky Lu
Chairman
Etron Technology
Eric Vittoz
Independent Consultant
Forums
Sunday, February 17
Advanced RF Transceiver Design Techniques
VLSI Power Management Techniques: Principles and Applications
Thursday, February 21
Emerging Technologies for Wireline Communication
Scientific Imaging
Frequency Generation and Clock Distribution
Mixed-signal/RF Design and Modeling in Next-Generation CMOS
Special Evening Topics
Sunday, February 17
"Batteries Not Included" — How Little is Enough for Real Energy Autonomy?
Much has been said about energy scavenging, and much has also been said about low-power circuitry. Both are essential parts of the energy equation. The goal of the panel is to present theoretical and practical issues as seen from both sides, mix in some system level techniques, and then debate the issues of real energy autonomy. How much must we generate? How much can we consume? Can we agree?
Tuesday, February 19
High-speed Communications on 4 Wheels — What's in your Next Car?
Communication within vehicles is increasing to support emerging applications, such as: Infotainment, Driver Assistance, Safety Systems. and Diagnostics; but, these all require per-channel data rates beyond those now offered. Correspondingly, the number of networked nodes per car continues to increase: In 2010, 650 million automotive communication ports were shipped. In view of the fact that cabling is the third-largest cost factor, and the third-heaviest component in the car, there is a clear need to replace current low-data-rate solutions by high-rate backbone networks. Currently, car makers and silicon manufacturers are advancing electrical and optical solutions. This session will provide an overview of the status and future trends for electronics inside the car, with emphasis on present and future challenges for wireline commuications.
Student Initiatives
Sunday, February 17
Student Research Preview : Poster Session w/ Short Presentations
Research with Innovation is Power for Promising Career Growth
Speaker Nicky Lu, Chairman, Etron Technology
Silkroad Award
Scholarships awarded for Far East full-time students!
Evening Panels
Tuesday , February 19
You're Hired — The Top 25 Interview Questions for Circuit Designers
Rightly or wrongly, circuit designers must undergo several technical interviews before landing their dream job. While many students and practitioners feel confident that they have a strong and intuitive understanding of circuits, even the best can be stumped by exotic circuits or even by a basic misunderstanding of fundamental concepts. This panel will challenge and entertain the audience and each other with questions that often arise during job interviews. The audience can judge which interview questions are fair game in the pursuit of the highly-coveted mixed-signal integrated circuit job.
SoCs Empowering 2020 killer applications
What are the SoCs driving killer applications in 2020? Can we forecast these killer applications? We have experienced the evolution of computers, communications, and now sensing: Are sensors driving the next killer applications? What circuits and system innovations can the solid-state industry create to motivate new killer applications? What technology elements, device structures, and memory architectures are required? Should we continue with silicon, and seek breakthroughs in system architectures, algorithms, SoC integration, and packaging? Or, should we prepare "beyond-silicon" technologies? Are "beyond silicon" technologies realistic in the forseeable future?
Short Course
Thursday, February 21
RF Blocks for Wireless Transceivers
Hooman Darabi, Broadcom, IC's for Communications
John Long, Delft University of Technology, VCO's, Design of Building Blocks for the RF Transceiver Front-End
Ali Hajimiri, Caltech, High frequency CMOS Power Generation and Phased-array Transmitters
Ali Niknejad, UC Berkeley, Millimeter-wave Phased-array Receivers
Tutorials
Sunday, February 17
Basics of 60GHz LNA and PA Design in CMOS
Piet Wambacq, imec
High-Bandwidth Memory Interface Design
Chulwoo Kim, Korea University
Circuit Design using FinFETs
Bing Sheu, TSMC
Simulation Techniques for Data Converter Design
Shanthi Pavan, Indian Institute of Technology, Madras
On-Chip Voltage and Timing Diagnostic Circuits
Frank O'Mahony, Intel
SoC Design Methodology for Improved Robustness
Anthony M. Hill, Texas Instruments
Wireless Transceiver System Design for Modem Communication Standards
Iason Vassiliou, Broadcom
Energy Harvesters and Energy Processing Circuits
Yogesh Ramadass, Texas Instruments
Data and Power Telemetry for Implants
Maurits Ortmanns, University of Ulm
Design of Voltage References
Wing-Hung Ki, Hong Kong University of Science and Technology
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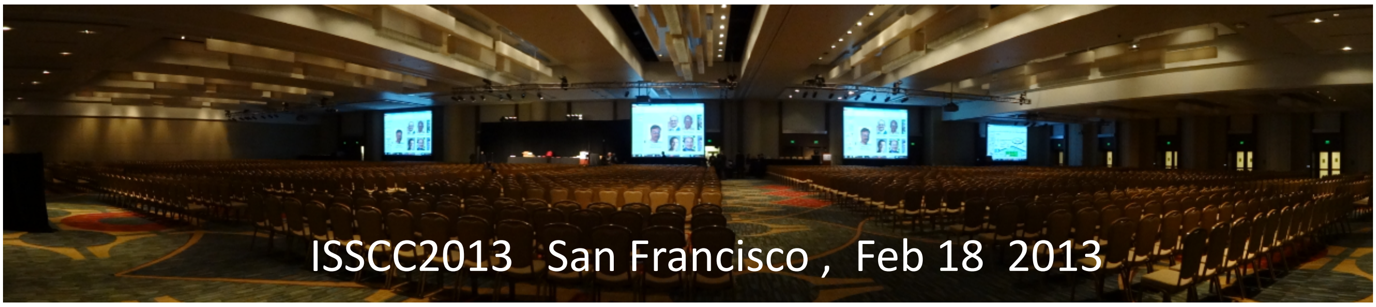
Mead co-authored a seminal text on VLSI design.

The professor emeritus of Caltech noted his own work and that of Intel's Gordon Moore in 1967 predicting advances of more than an order of magnitude in semiconductor physics. "Most people thought we were crazy… [but] after a few years it became the industry road map," he said.

Mead's keynote followed a talk describing heroic efforts to create extreme ultraviolet lithography systems that aim to continue progress in chip technology.



News & Analysis

ISSCC 2013: Combining old with new

Nicolas Mokhoff

11/19/2012 9:00 AM EST

MANHASSET, N.Y. -- The venerable International Solid-State Circuits Conference this February will make the most of commemorating its three-score history by digging for past innovations in its "innovations attic" which are still pertinent today.

At the same time, ISSCC organizers also want to look ahead by offering its young ones tips on getting a circuit designer's job.

Trudy Stetzler, distinguished member of the technical staff at Texas Instruments and ISSCC 2013 program vice-chair, has organized a panel of six experts from academia and industry to dig into their memories and find lost treasures in circuit design.

The panel promises surprises from the past sixty years as panelists explain why the concepts are significant today and should be pulled from the "innovation attic". As the preliminary program states: "When you clean up your attic you may find things that you have totally forgotten about: old toys you used to play with, old books with lost stories. And then you think back to those past days and view them in the context of today's busy life."

The six panelists include Robert Brodersen, University of California, Berkeley, CA; Rinaldo Castello, University of Pavia, Pavia, Italy; Yoshiaki Daimon Hagihara, Sojo University, Kumamoto, Japan; Thomas Lee, Microsystems Technology Office, DARPA, Arlington, VA; Nicky Lu, Etron Technology, Hsinchu, Taiwan; and Eric Vittoz, Independent Consultant, Cernier, Switzerland.

The next generation Super High Vision (SHV) Television System around 2020 needs a very low-light sensitive and high-definition image sensor of 33 Mega pixels with 120 picture frames per second. How can we make it ? John Louis Moll (1921-2011) obtained the B.Sc. in Physics and the Ph.D. in Electrical Engineering in 1943 and 1952 respectively. His well-established Ebers-Moll transistor model, and the theory of the p-n-p-n switch (Proc.IRE, vol,44, pp.1174-1182, 1956) came from this effort. Extended concepts of photo-diode and photo-transistor models became essential to realize image sensors. Now, incorporated with compact column ADCs and smart real-time comparator shift-registers, possibly in 3D circuit integration, this classical p-n-p-n switch may help us to obtain a design solution for the high-performance and highly intelligent camera system that can serve us at home in each family as a human-friendly Artificial Intelligent Partner System (AIPS).


ISSCC2013 San Francisco , Feb 18 2013
LU
CASTELLO
VITTOZ
BRODERSEN
CHANDRAKASAN


CASTELLO
HAGIHARA
VITTOZ
BRODERSEN


HAGIHARA


Sojo University, Kumamoto-city, Japan
CHANDRAKASAN

ISSCC2013 San Francisco

Yoshiaki Daimon Hagihara

(1) Thank you, Anantha-san.

Good evening, ladies and gentlemen.
And a happy 60th anniversary to ISSCC2013.

I thought I was invited as an old boy for this special occasion since I had been involved and served for many years in this ISSCC community. But I received a homework and was asked to prepare for a short talk on this panel. It was a very difficult subject. So, the first thing I did was, look around for my old books and notebooks in my house and office.

Digging lost treasures in circuit design out of my old books....

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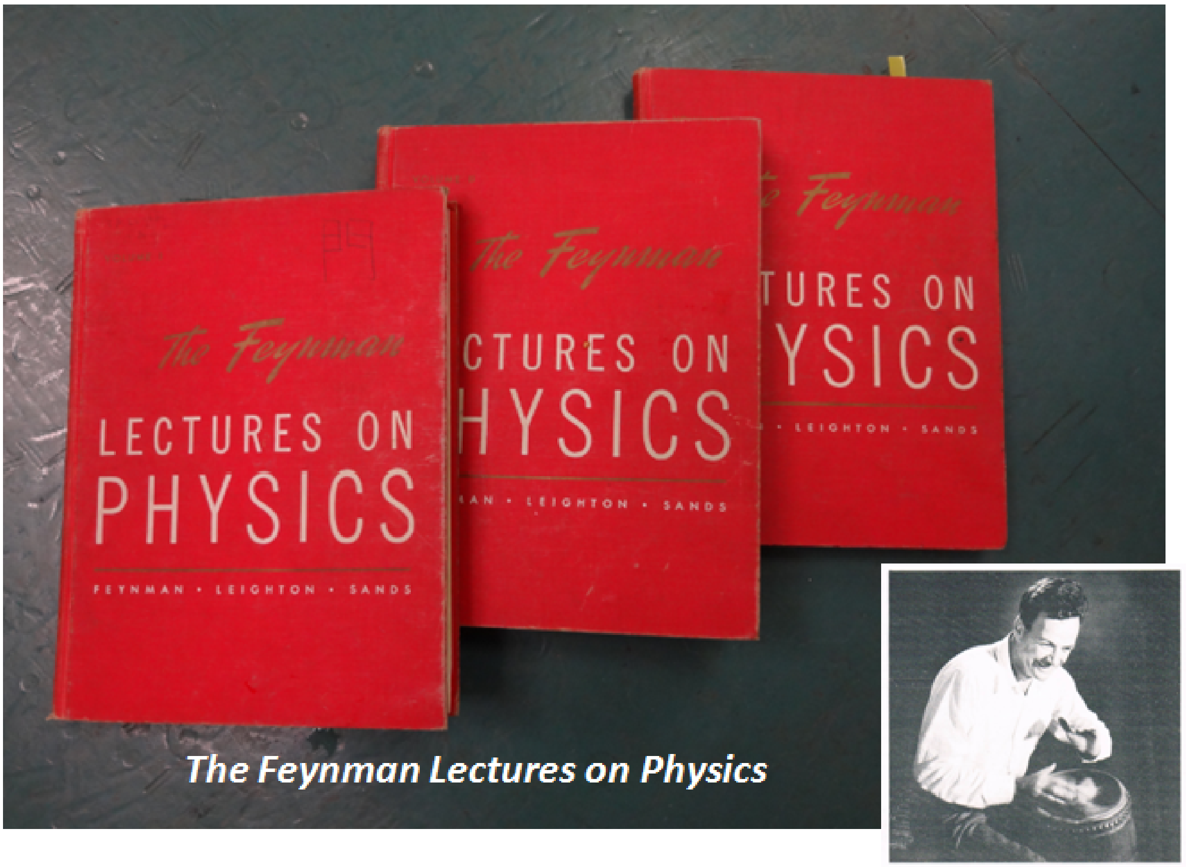
Yoshiaki Daimon Hagihara

(2) I found some , I sorted them out, and put them together on my bookshelf. Here they are.

This evening, if I am allowed to introduce you only one unique circuit application , it would be a circuit application of a p-n-p-n diode structure.

In a normal operation mode, this device works as a Thyristor , which can drive a large current and can make even a big linear motor car float and move very swiftly. On the other hand, when this is in off-state, it has very, very small leakage current, which is very important for our modern society seeking for low-power Energy-saving systems.

And in a dynamic operation mode, this device may work as a simple p-n-p-n capacitance , that can detect and store one single electron. I think this is a key device of an image sensor.



The Feynman Lectures on Physics

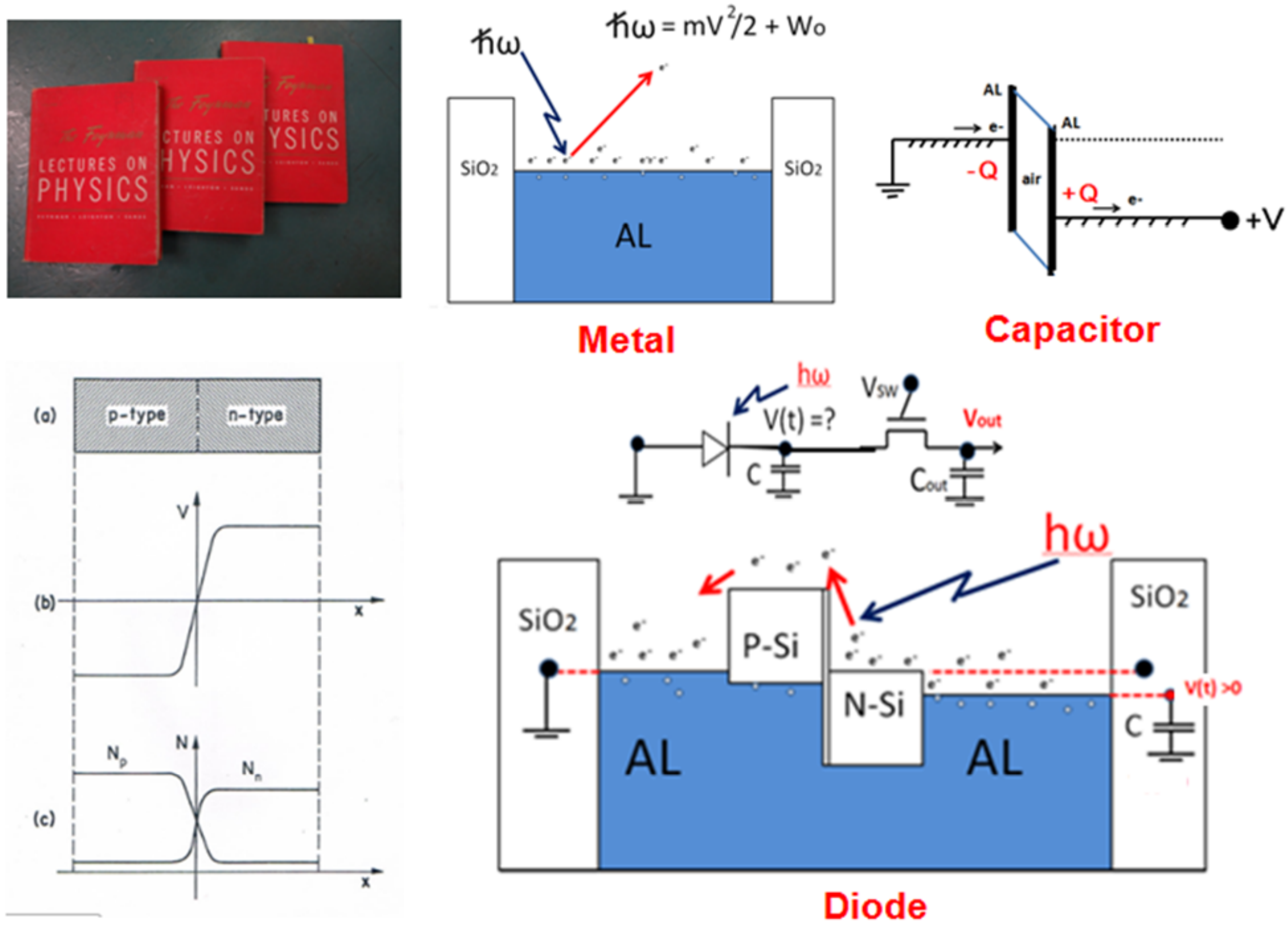
ISSCC2013 San Francisco **Yoshiaki Daimon Hagihara**

(3) There are many physics involved to understand this p-n-p-n diode structure and its related circuit behaviors.

So I tried to recall my freshman year in college, when I was taking a physics course.

Prof. Leighton, and sometimes Prof. Feynman himself, gave us lectures. Their lectures were always fascinating to us.
They always tried to appeal intuitively to our young minds.

Feynman once said that an electron is always free, moving around rapidly in free space, even in a solid, and it never stops. It is very hard to catch. We don't know exactly where it is. Our civilization is based on the technology of controlling a single electron.



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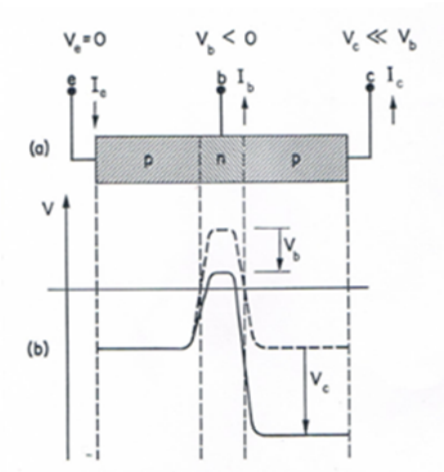
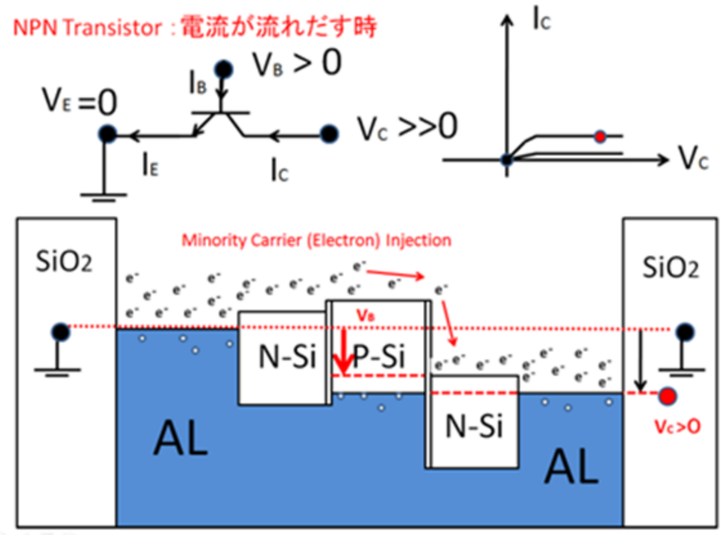
Yoshiaki Daimon Hagihara

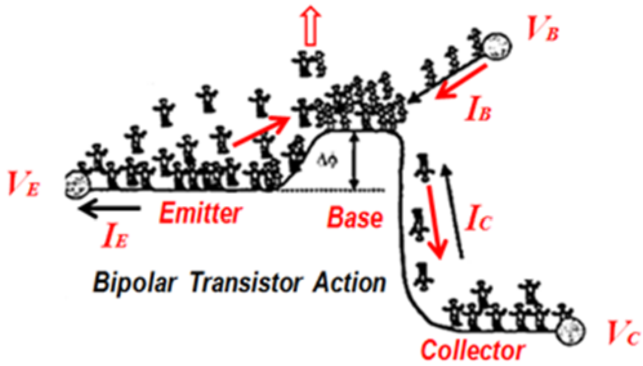
(4) So I was always being guided to try to understand physics by paying a special attention to the behavior of one single electron interacting with a photon in a solid , in a metal , in an insulator , in a capacitor, in a p-n junction and in a transistor.

A p-n junction is also called a diode, a rectifier , a LED , a solar cell or simply a p-n junction capacitor depending on how we want to use it. If we don't want to use, but if it is still there, I learned later that it is also called a parasitic p-n junction capacitance, which is a very important circuit element for predicting a very complicated VLSI circuit performance in some cases.



Bipolar Transistor





ISSCC2013 San Francisco　　Yoshiaki Daimon Hagihara

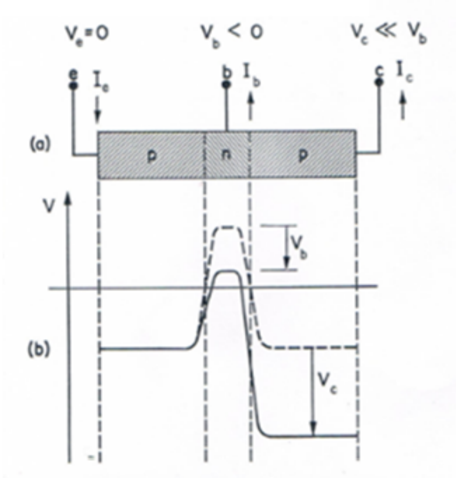
(5) I thought I had a very good background in Feynman physics. Feynman physics always talked about the behavior of one single electron in free space and in a solid. The situation gets more complex when an electron interact with a photon.

Well, a picture is worth one thousand words.

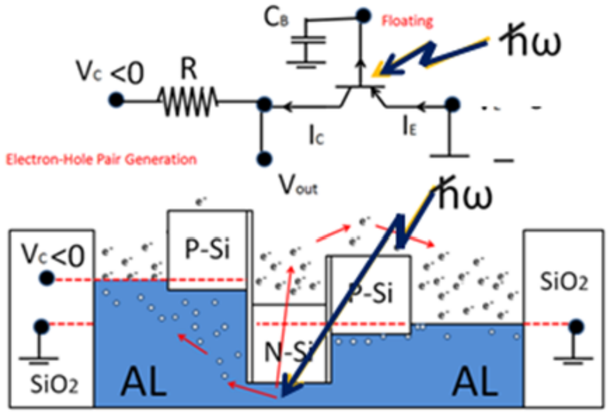
This is a picture of boys trying to catch a girl on the hill top but most of the boys are guided to the collector junction cliff and fall down to be collected at the collector terminal.

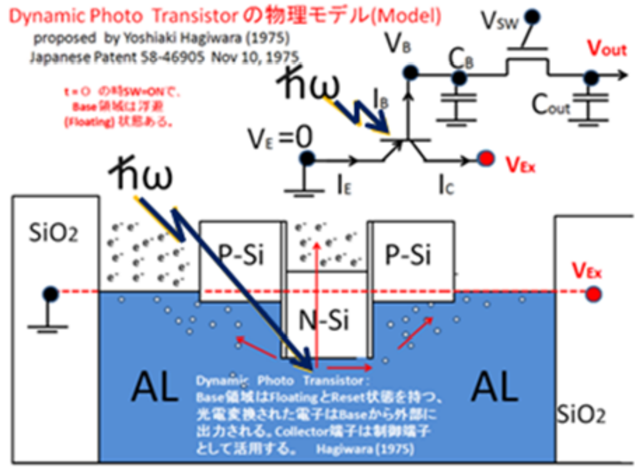
And only a few boys out of say 100 energetic boys can catch a girl on the hill top and they can recombine and become happy. And the pair can produce a baby-photon.

This is in a sense a light emitting photo-transistor with a very poor efficiency of a few percents...



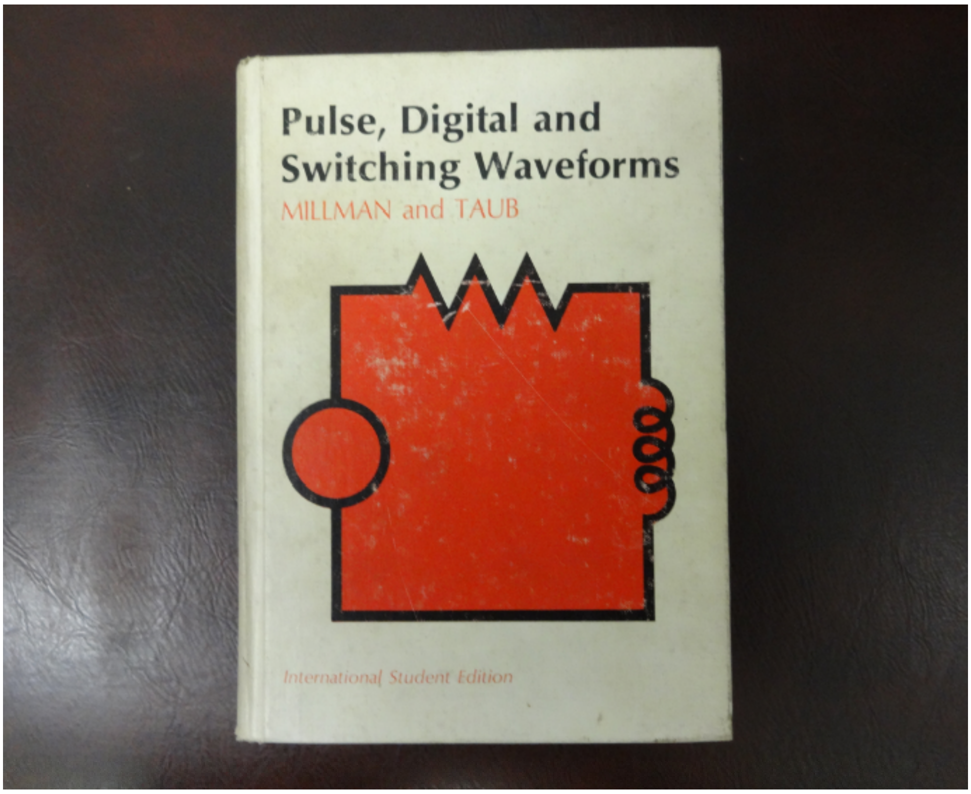
Bipolar Transistor





ISSCC2013 San Francisco **Yoshiaki Daimon Hagihara**

(6) And this is a picture of an incoming photon incident to the bipolar transistor base region. The photon energy creates an electron-hole pair and the photo-electron can be stored in the base as the majority carrier. So I see that a bipolar transistor can also function as a photon detector and/or a storage container. As you know, a room in a hotel must be empty and clean before the first hotel guest arrives. So must be this transistor base region empty and clean with no guest electrons at the beginning. In this way, I thought a transistor is useful since it can capture, confine and control one single electron. But I did not know yet how to move that single photo-electron in the base container to the outside terminal so that we can use it as a signal. That is, I had no way yet to know whether the guest has checked in the hotel and resting in the hotel room. I had no way yet to ask the hotel guest to come up to the hotel lobby to meet me. I had to wait a few more years to find the answer. We all know now it is CCD, a charge coupled device that is a series of capacitance that can store and transfer one single electron. With a output circuit of a pre-charge reset set gate and a source-follower circuit we can finally meet our hotel guest at the hotel lobby !



Digging lost treasures in circuit design
out of my old books....

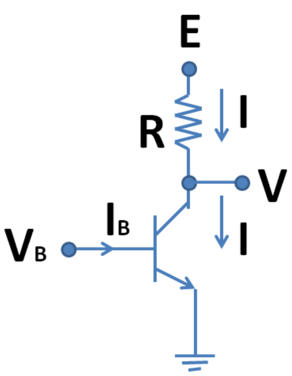
ISSCC2013 San Francisco

Yoshiaki Daimon Hagihara

(7) Now, the second book I studied was "Pulse, Digital and Switching Waveforms" by Millman and Taub.

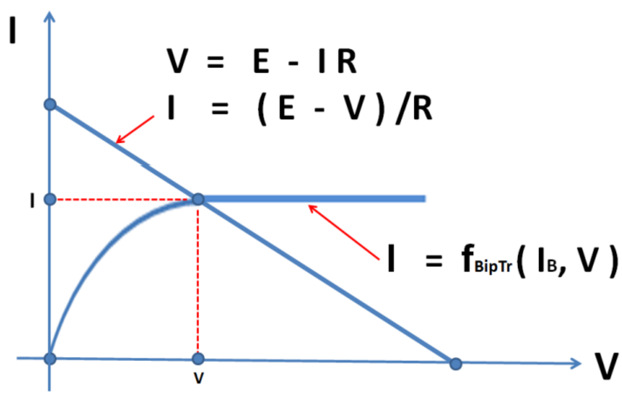
This book introduced me many basic bipolar transistor circuits.

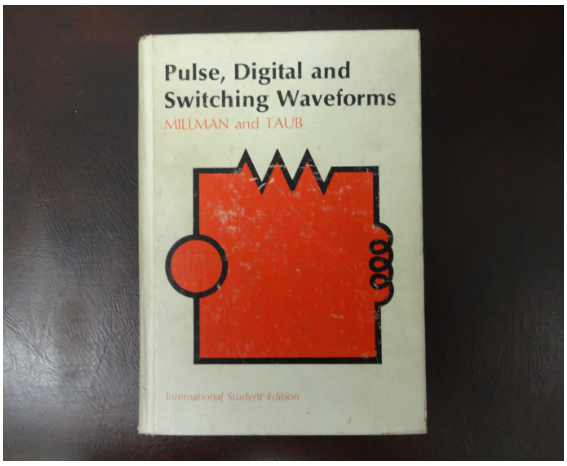
I learned many circuits such as a simple inverter or a linear amplifier with a simple resistor-load, the concept of load-line.

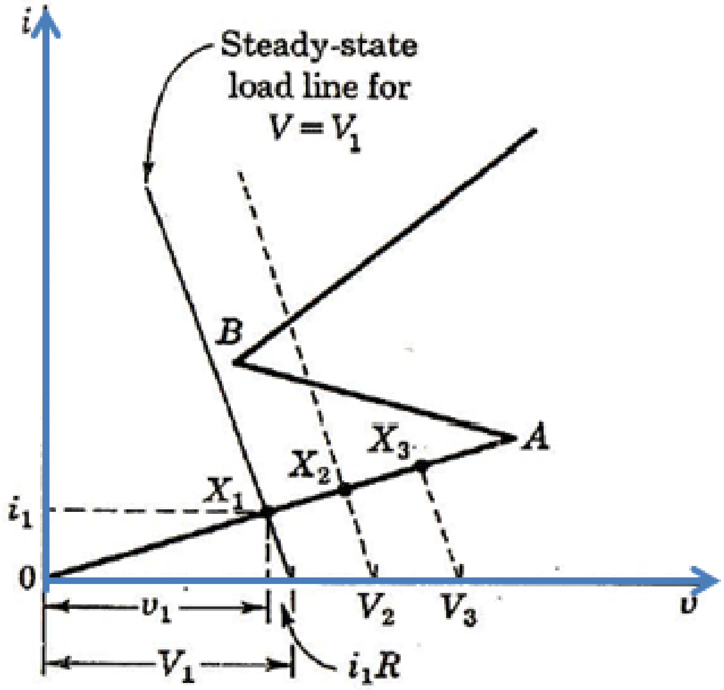


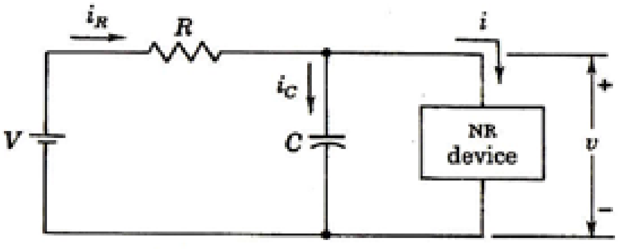
$$V = E - IR$$
$$I = (E - V)/R$$

$$I = f_{BipTr}(I_B, V)$$









Negative Resistance I-V

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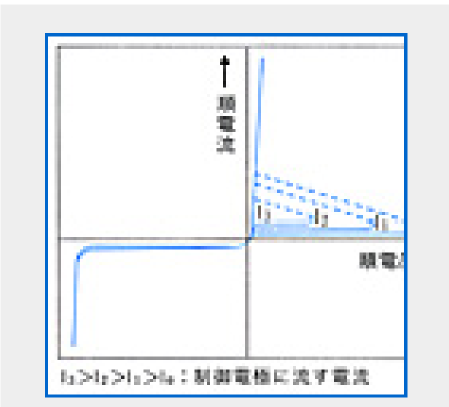
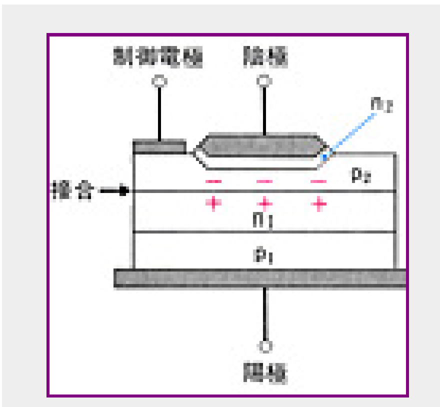
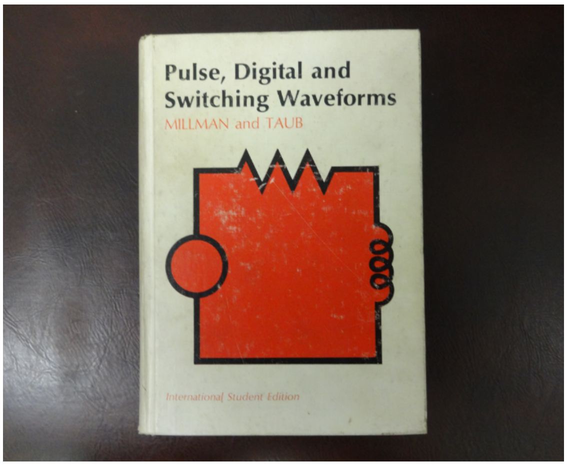
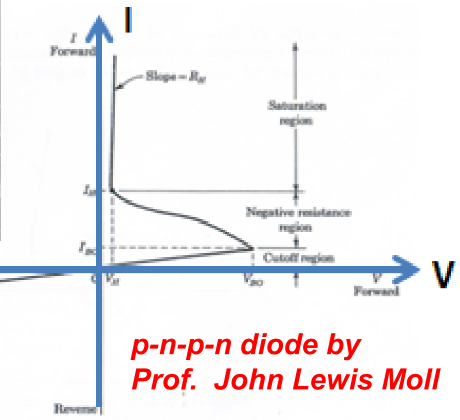
Yoshiaki Daimon Hagihara

(8) This book also introduced me many important electronic devices and their related circuits such as a negative-resistance circuits utilizing a device which is called a thyristor, or SCR (Silicon Controlled Rectifier), or simply a p-n-p-n diode, depending how you want to use the device.

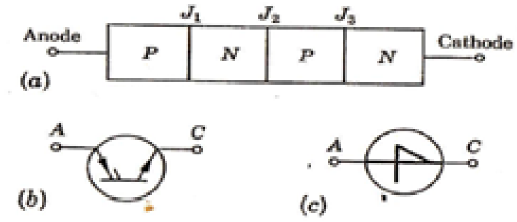


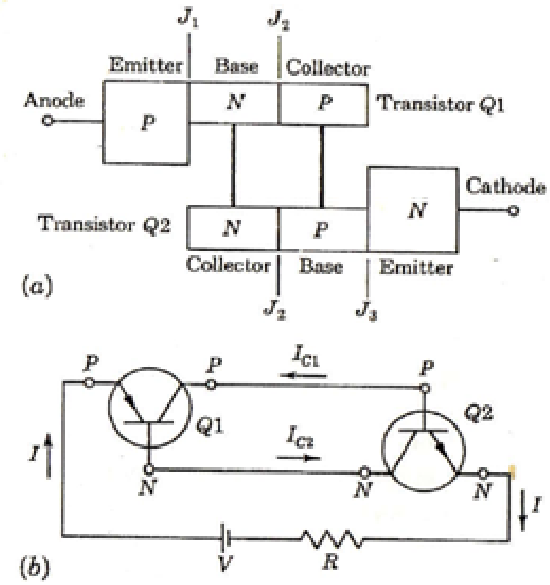






p-n-p-n diode by
Prof. John Lewis Moll





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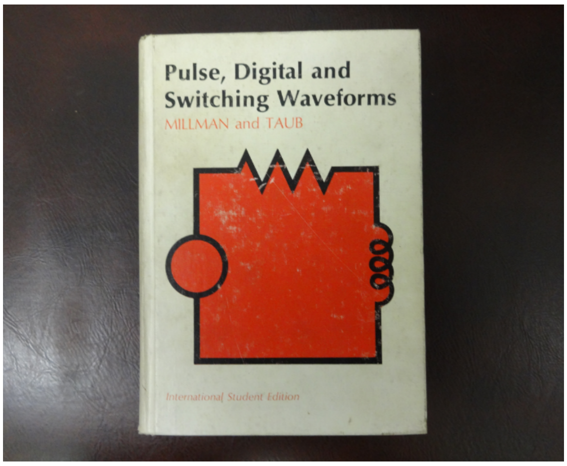
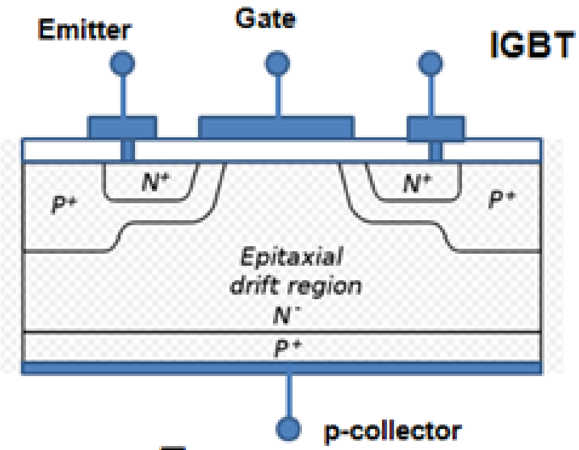
(9) The p-n-p-n diode consists of one p-n-p transistor and one n-p-n transistor, working together as a team. As you know, when two people work together hands in hands as a team, we should expect a good work from them, an entirely new creative, wonderful performance from the collaboration of the two people.

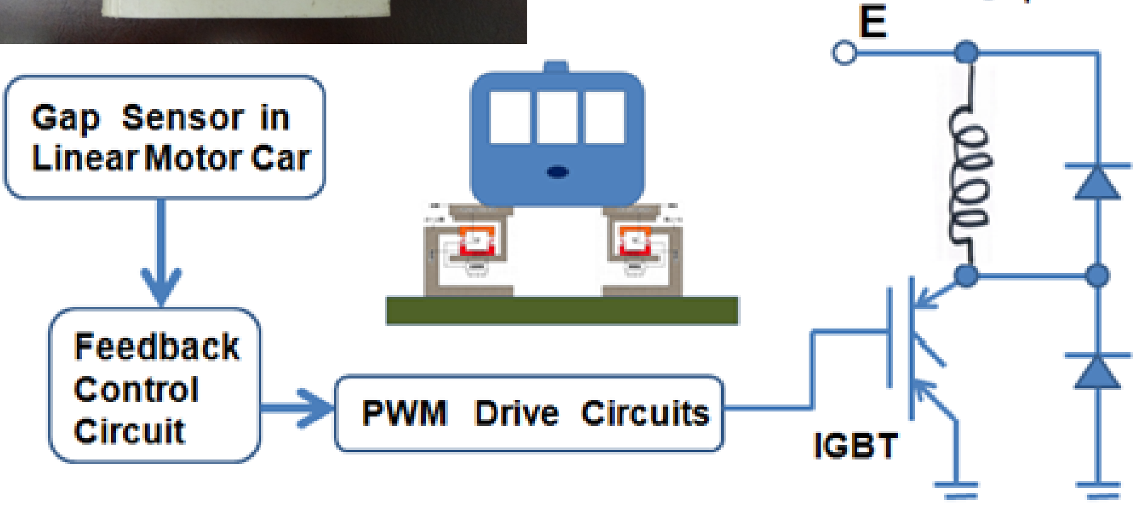
This p-n-p-n diode can also be called a p-n-p-n thyristor , a SCR switch, a p-n-p-n double-transistor structure, or simply a p-n-p-n diode capacitor , depending on the operation modes.

I learned this p-n-p-n diode switch, too. During its OFF-state, it has a very low leakage current . This device was originally studied and reported in details by Prof. John Lewis Moll in his PhD thesis work and in subsequent papers, which I studied and learned.

During its ON-state, a very, very large electrical current , and can drive a big heavy train or automobile.







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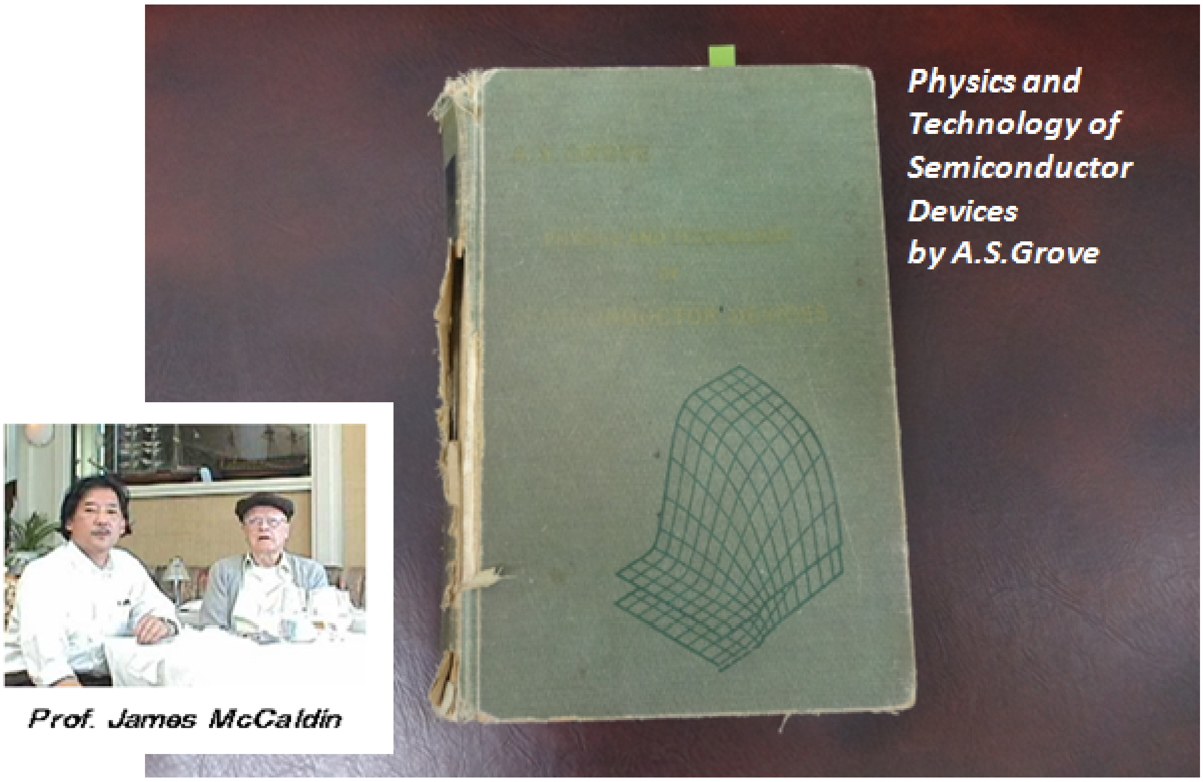
(10) A slight modification of this p-n-p-n diode gives us another very useful device, which we call Insulated Gate Bipolar Transistor. This is a key device for a linear motor car of the future ! This is a simple inverter circuit with an inductance coil as the load element and the driving device is an Insulated Gate Bipolar Transistor with the PWM control input.

The PWM, Pulse Width Modulation, techniques is a very powerful and useful digital circuit system technique now universally applied for driving servo motors for many mechanical system applications including Robotics. This PWM circuit technique is useful to control the On-AND-OFF Digital current flow in the magnetic coil used to make a linear motor car to float and move in the air.

In a special dynamic operation mode, this device also works as a simple p-n-p-n capacitance that can detect one single electron . And it works as a key device element in modern imagers.



Prof. James McCaldin

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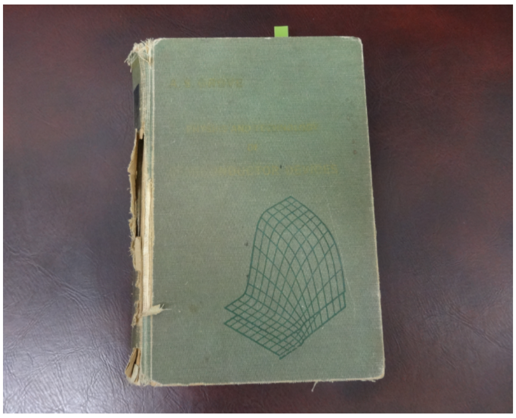
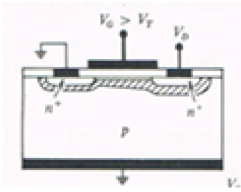
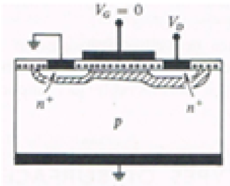
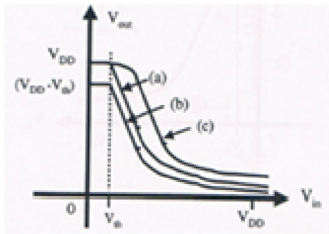
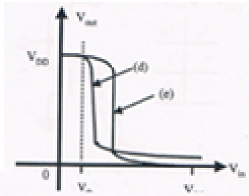
(11) Then the third book I studied, with the guidance of Prof. John McCaldin, was " Physics and Technology of Semiconductor Devices" by Andy S. Grove.

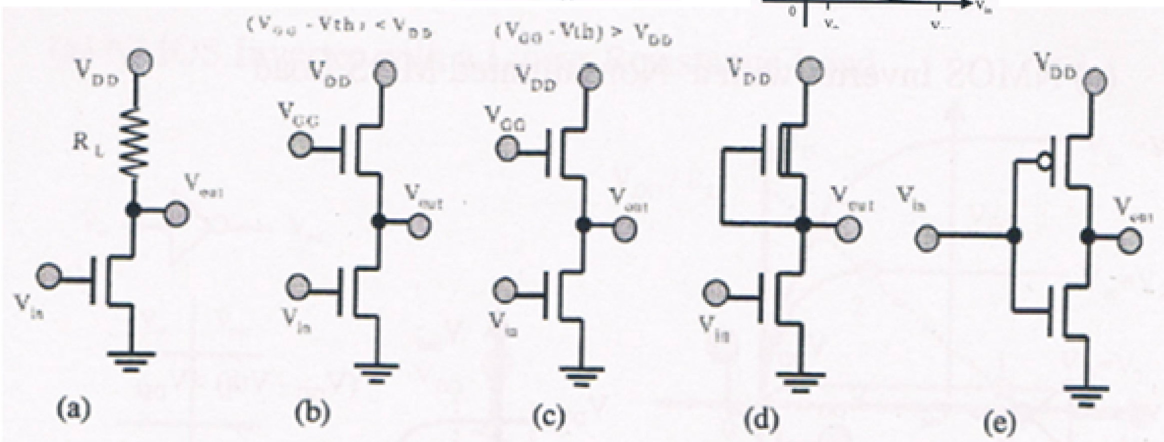












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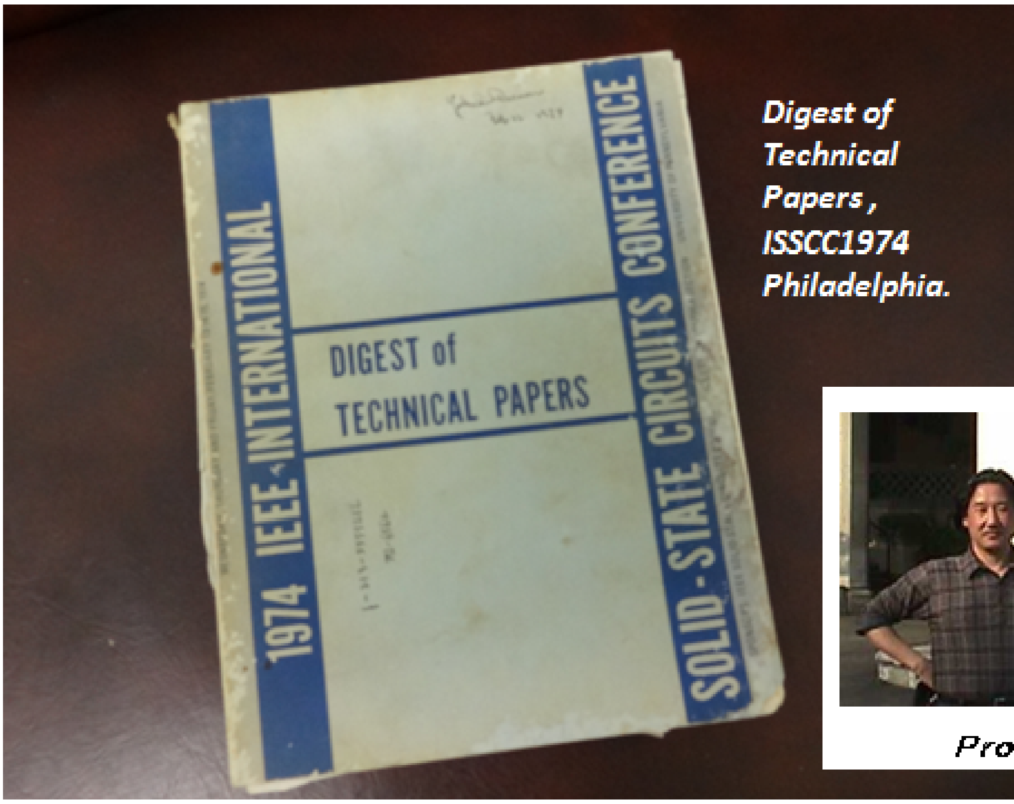
(12) I learned MOSFETs and many types of inverters.

Among them, only a CMOS inverter seems surviving now….



Prof. T. C. McGill

Digging lost treasures in circuit design out of my old books....

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(13) When I was about to start my graduate work, I learned about a new device called CCD. I thought we now have a device to detect the arrival of the first guest electron in our empty hotel room !

With this device I thought I could ask the guest electron to come up to the hotel lobby to meet us !

I was excited . I thought this is the device we were looking for, that can transfer one single electron in solid from one place to another and to the final output circuit stage.

I was excited, and many people were also excited ! Many researchers worked on this device with great expectations.

I was excited and worked on this device with the guidance of Prof. T.C. McGill .

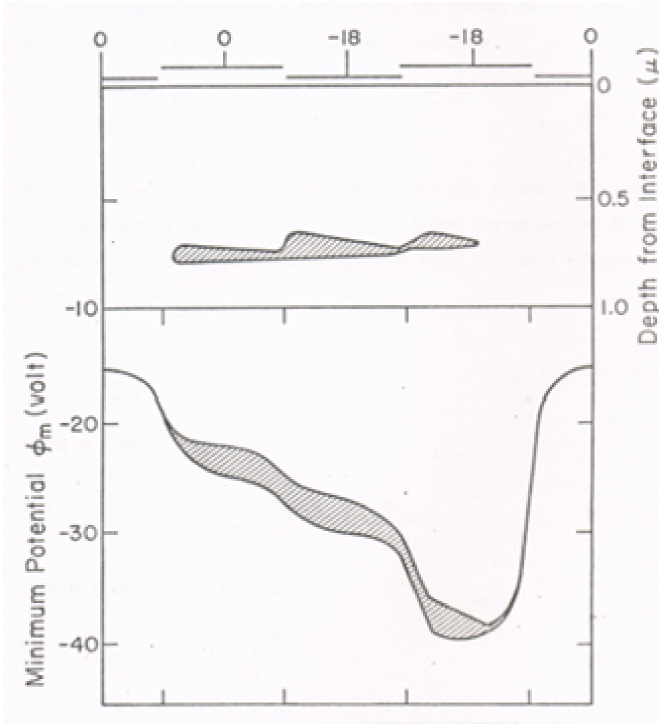
Charge-Coupled Devices and Applications

Chairman

Lewis M. Terman

Testimonial to the importance of the charge-transfer phenomenon is attested to by the Morris N. Liebmann and the David A. Sarnoff awards this year to the originators of the charge-coupled and bucket-brigade devices, respectively. The papers in this session concentrate on the former.

Charge-coupled devices are unique among semiconductor elements. In all other device embodiments into circuits, charge is manipulated and extracted and then used to charge a capacitor or passed through a resistor in each case to develop a signal voltage. In



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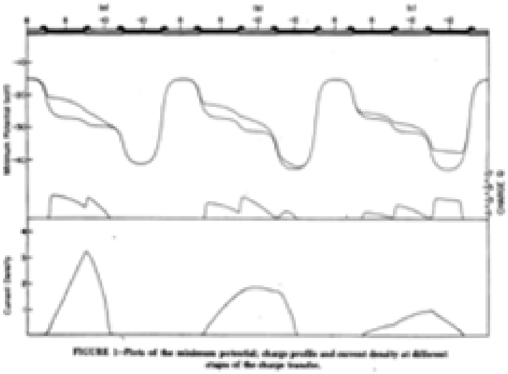
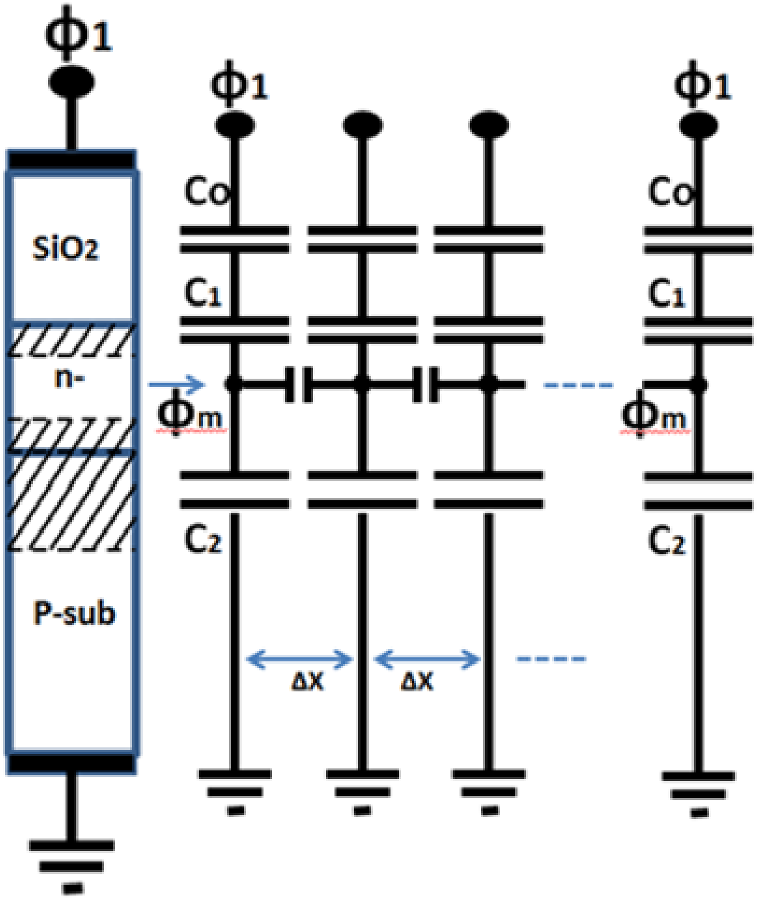
(14) I was specially interested in a buried channel CCD structure since this device protects a single electron, our important hotel guest from being trapped by the Si-SiO2 interface states.





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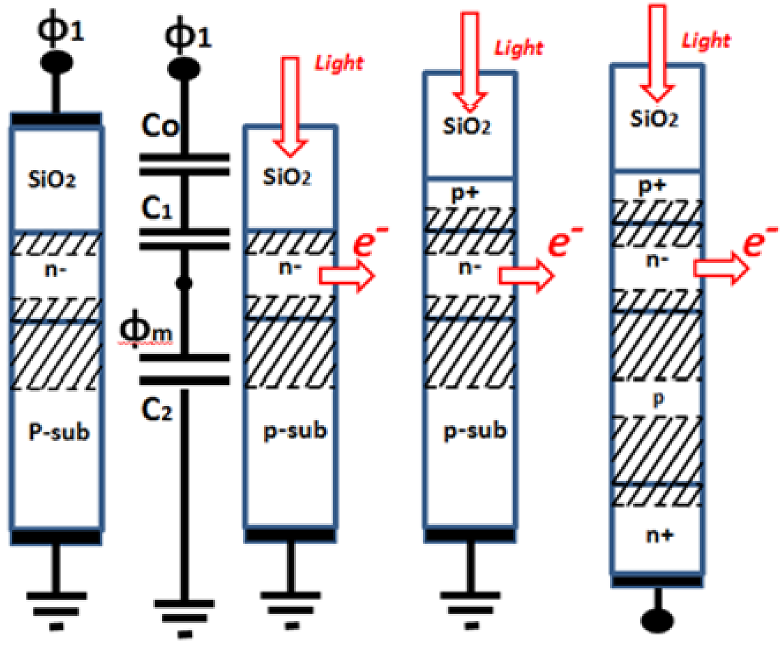
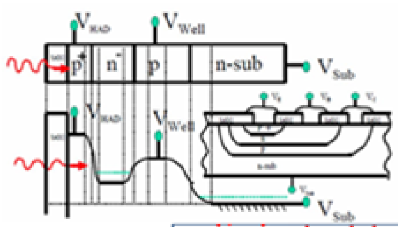
(15) This is a capacitance network that one single electron, our hotel guest, would see inside a buried channel CCD structure.

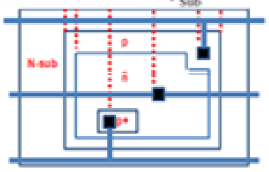
The single electron is well protected, and can be transferred safely along the buried channel by controlling gate voltages.

Originally I expected this device to become a highly sensitive imaging device, a low-light imaging device with very low noise.



Hagiwara, 1975





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(16) But soon I found out this is no good for imaging.
It has a metal layer on the top!
The metal layer does not allow light to pass through.

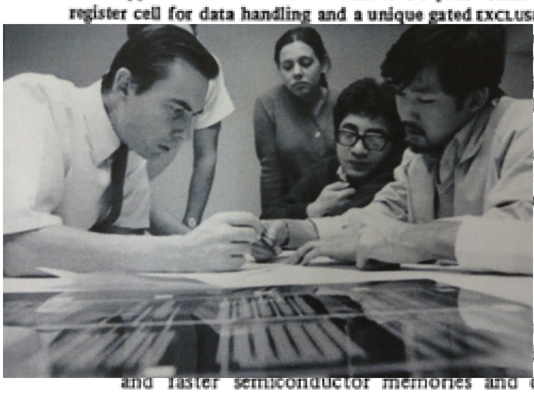
So we still needed the original photo-diode, the photo-transistor, and the p-n-p-n photo-diode that I had studied when I was an undergraduate student.

At least they can pass the light through the device and catch a single electron in the dynamic capacitance mode of their operations.

128-Bit Multicomparator

CARVER A. MEAD, RICHARD D. PASHLEY, MEMBER, IEEE, LEE D. BRITTON, YOSHIAKI T. DAIMON, AND STEWART F. SANDO, JR., MEMBER, IEEE

Abstract—A 128-bit multicomparator was designed to perform the search-sort function on arbitrary length data strings. Devices can be cascaded for longer block lengths or paralleled for bit-parallel, word-serial applications. The circuit utilizes a 3-phase static-dynamic shift register cell for data handling and a unique gated EXCLUSIVE-NOR circuit […] eration is per- […]" register with […] sable the com- […] hannel silicon- […] a 107 × 150 […] ransistor logic […] attained. The […] mode and 300



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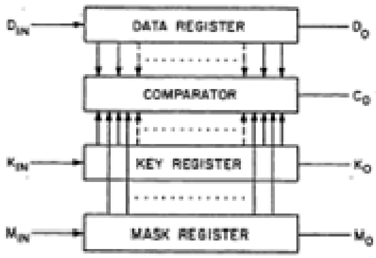
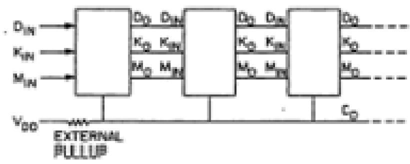


Fig. 1. Block diagram of multicomparator.



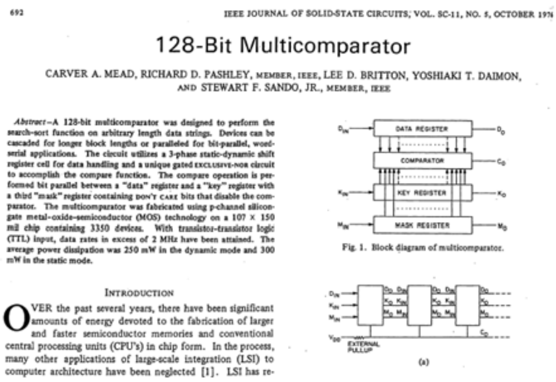
(a)

Journal of Solid State Circuits;VOL.SC-11,NO.5, OCTOBER 1976

ISSCC2013 San Francisco **Yoshiaki Daimon Hagihara**

(17)Now going back to 1971 again, right after I finished my undergraduate work. I was one of the students in the first year of the VLSI circuit design course taught by Prof. Caver A .Mead at Caltech in 1971.

Meanwhile, during my graduate work, we had a design project of a 128- bit multi-comparator silicon chip, that has three shift registers in parallel. They are called the Data, the Key and the Mask registers. The data in the registers is compared and matched by the comparator logic circuits, consisting of many EXNOR circuits.



692 IEEE JOURNAL OF SOLID-STATE CIRCUITS, VOL. SC-11, NO. 5, OCTOBER 1976

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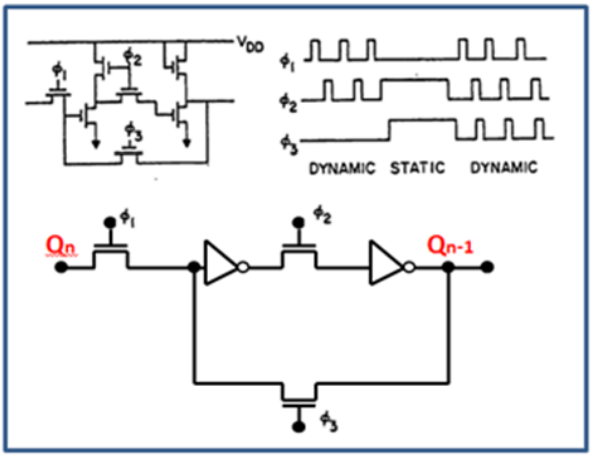
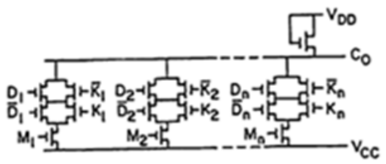
Fig. 1. Block diagram of multicomparator.

(a)

INTRODUCTION

OVER the past several years, there have been significant amounts of energy devoted to the fabrication of larger and faster semiconductor memories and conventional central processing units (CPU's) in chip form. In the process, many other applications of large-scale integration (LSI) to computer architecture have been neglected [1]. LSI has re-





M_i	D_i	$\bar{K}_i$	C_i
1	1	1	1
1	0	0	1
1	1	0	0
1	0	1	0
0	–	–	1

Gated EXCLUSIVE-NOR gate. (a) Schematic. (b) Truth table.

CalTech LSI Design Class, September 1971

● Exnor gate is important to detect the edge-effect:

$$ExNor(A,B) = A\,B + \bar{A}\;\bar{B}$$

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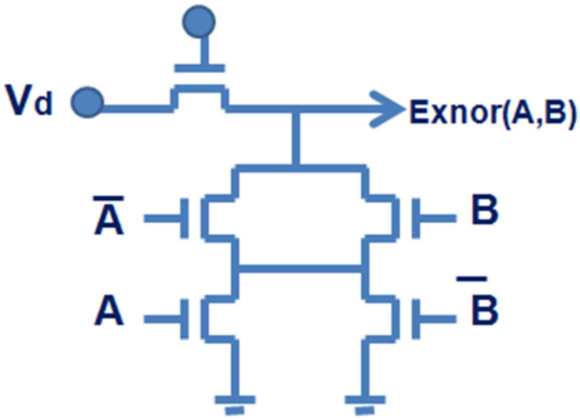
(18) The three shift registers are conventional ones.

A pair of inverters and three switching pass transistors as a group are functioning as a one-bit static memory cell or in other time as a one-bit shift-register element.

Exnor gate is important to detect the edge-effect. We can obtain a edge-enhanced picture by imposing on the original picture.



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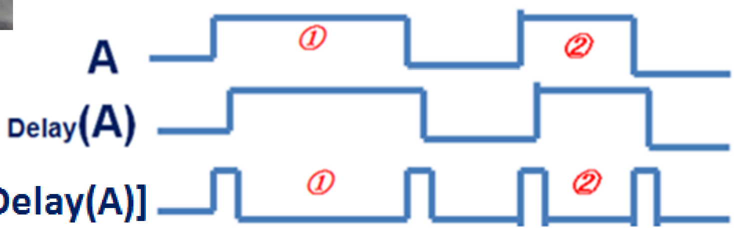

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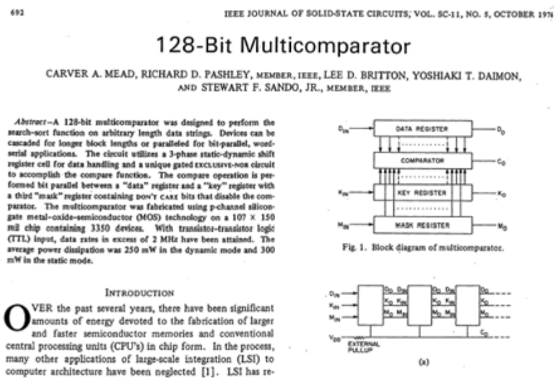
(19) The data in the register is compared and matched by the comparator logic circuits, consisting of many EXNOR gate logic circuits.

The EXNOR circuits are very useful for matching data and detecting the edge information.



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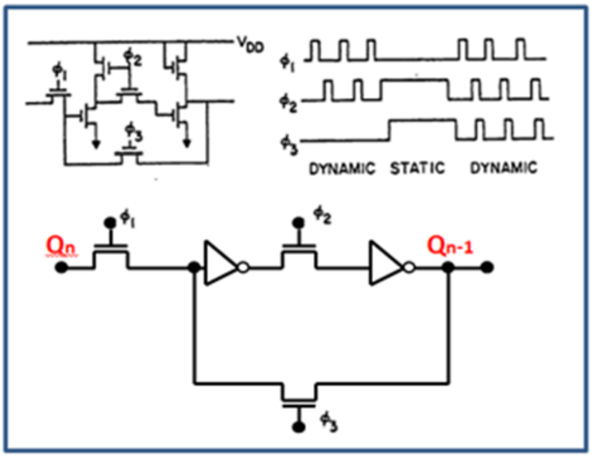
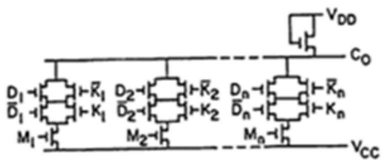
(a)

CalTech LSI Design Class, September 1971





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1	1	0	0
1	0	1	0
0	–	–	1

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● Exnor gate is important to detect the edge-effect:

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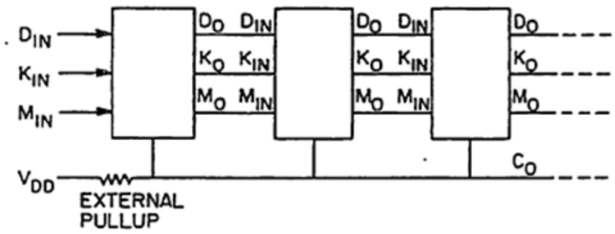
(20) This elementary EXNOR logic gate is frequently applied to compress image-data information.



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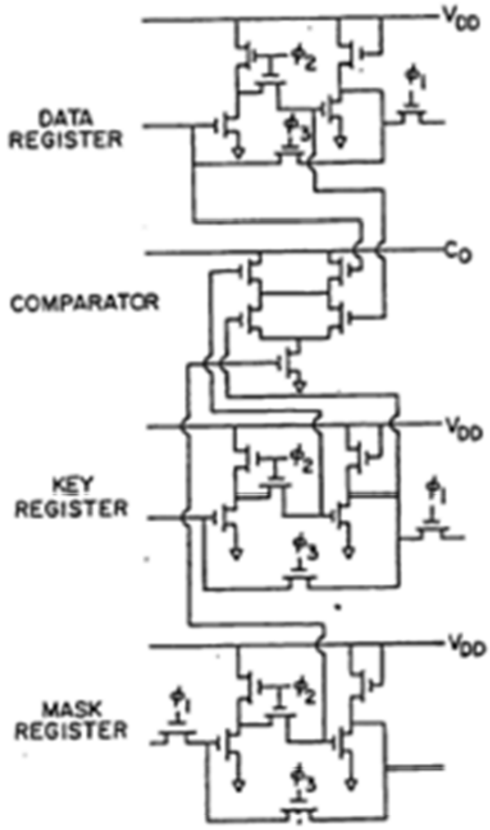

Full schematic of one bit slice of the multicomparator

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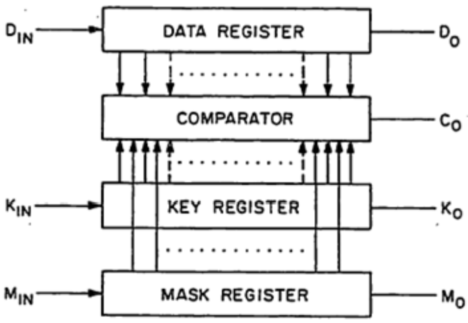
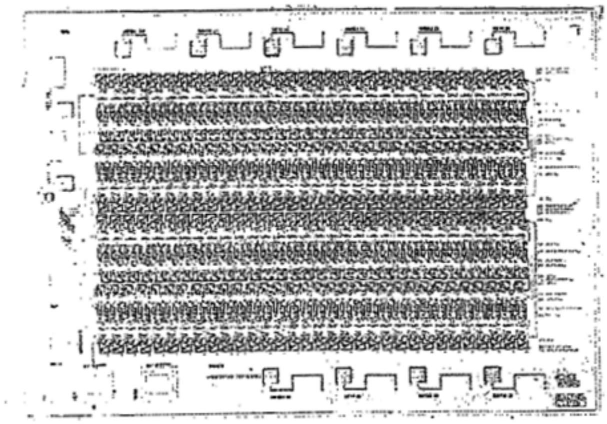
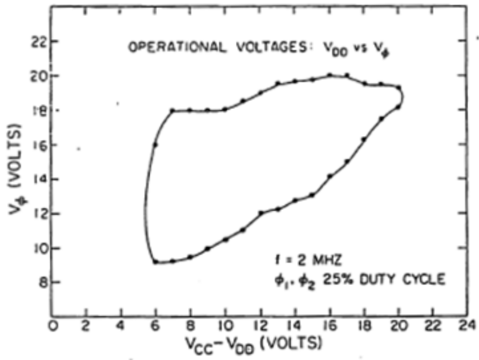
(21) This was a project, a challenge to design and build a real chip by Caltech students, and it was fabricated in Intel.



CalTech LSI Design Class, September 1971

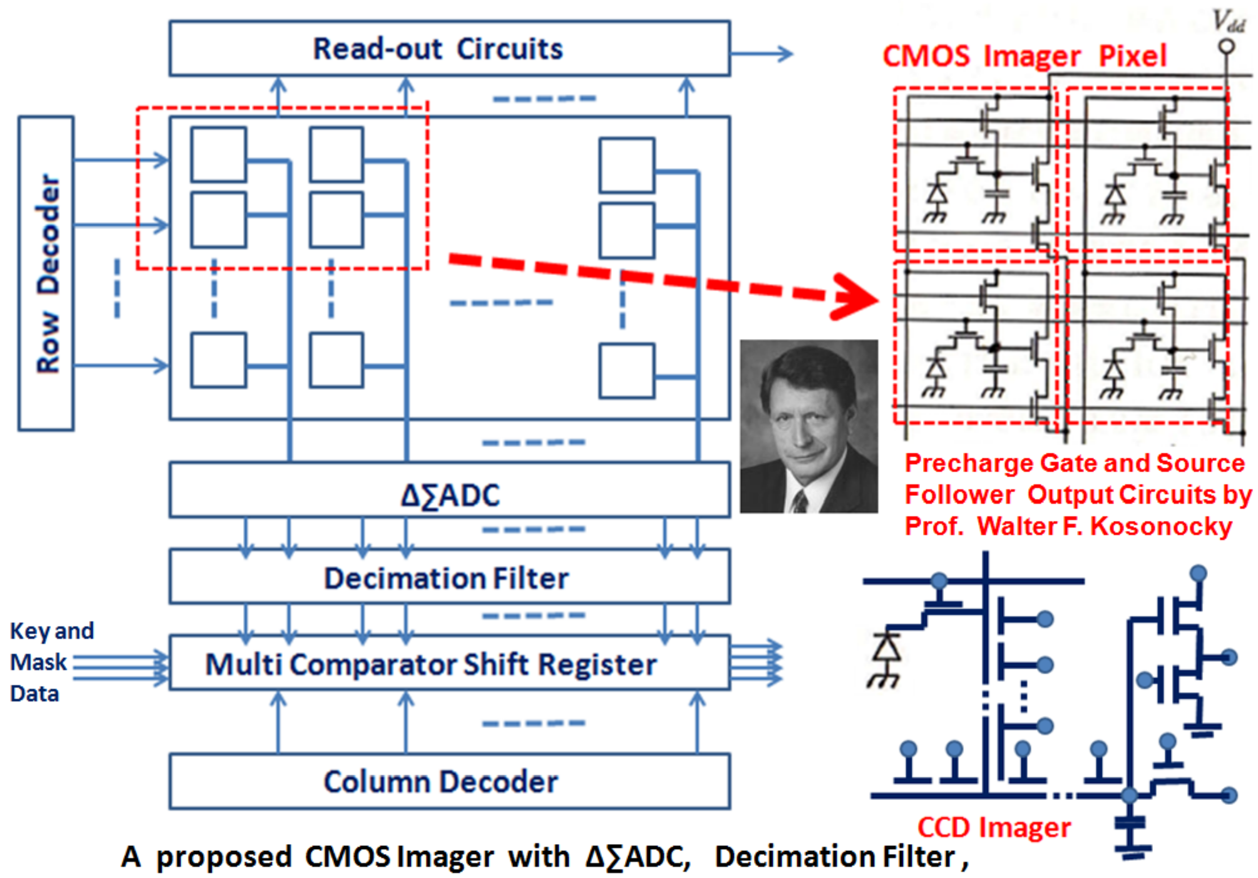




Yoshiaki Daimon Hagihara

(22) It is the VLSI chip built and reported for the first time in the world by university students with helps of industry.

I think this 128 multi-comparator chip may be still useful .



A proposed CMOS Imager with ΔΣADC, Decimation Filter, Key and Mask Data input and Multi Comparator Shift Register

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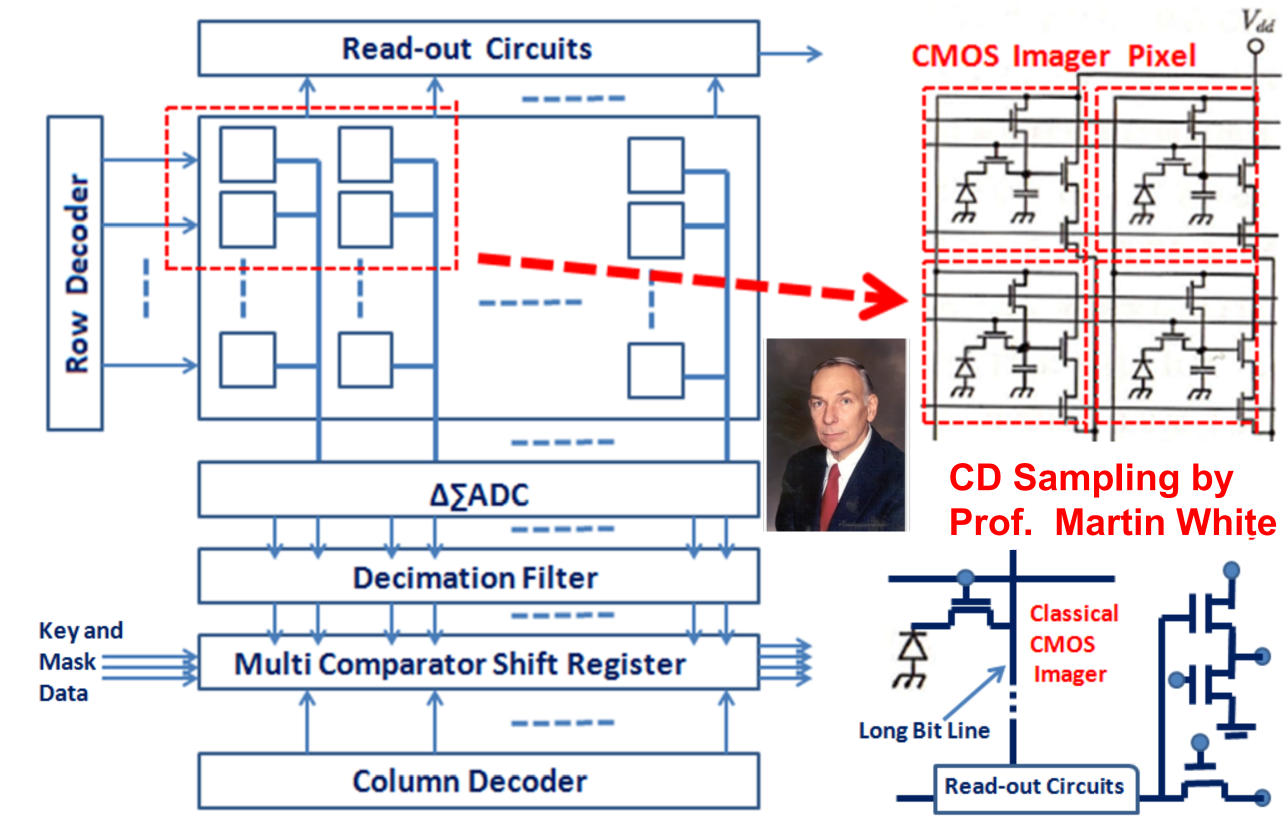
(23) I am just curious to find out if we can include this multi-comparator shift registers in the output circuit block of a CMOS Imager.

The output circuit block is very, very important.

The original output circuit is a simple combination of a pre-charge reset gate and a source follower.

I believe this output circuit was first proposed and reported by Dr. Walter F. Kosonocky.

I studied many of his papers when I was working on my PhD thesis in Caltech. I met him many times. He guided me a lot. He was famous and great . He was also my mentor.



A proposed CMOS Imager with ΔΣADC, Decimation Filter,
Key and Mask Data input and Multi Comparator Shift Register

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(24) Later a very useful and powerful operation mode, called Double Sampling, was proposed by Prof. Marvin White.

This technique accelerated drastically CMOS imager developments and revolutionized our imaging device industry.

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(25) I believe these people who worked on MOS Transistors, Memory Devices and Imaging devices are the ones worth recognition not only from our solid state circuit society but from the entire world .

I was surprised and amazed that in this way so many people, through many yeas of their diligence, contributed so much for the entire world we live in. Thank you !

Yoshiaki Daimon Hagihara

@ ISSCC2013 Plenary Panel , in San Francisco, California USA

Monday Evening February 18, 2013


ISSCC2013 San Francisco , Feb 18 2013


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