Bipolar Transistors/IC's in the Lehigh Valley and Beyond

by

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- LVSSCS Meeting, Oct. 20, 2016

Outline

- About the Speaker
- Point Contact, PNPN, and Microwave Transistors
- Allentown and Reading, a little history
- How to Design an Dial Chip Oscillator
- BCTM (Bipolar Circuits and Technology Meeting) a unique conference emphasizing bipolar

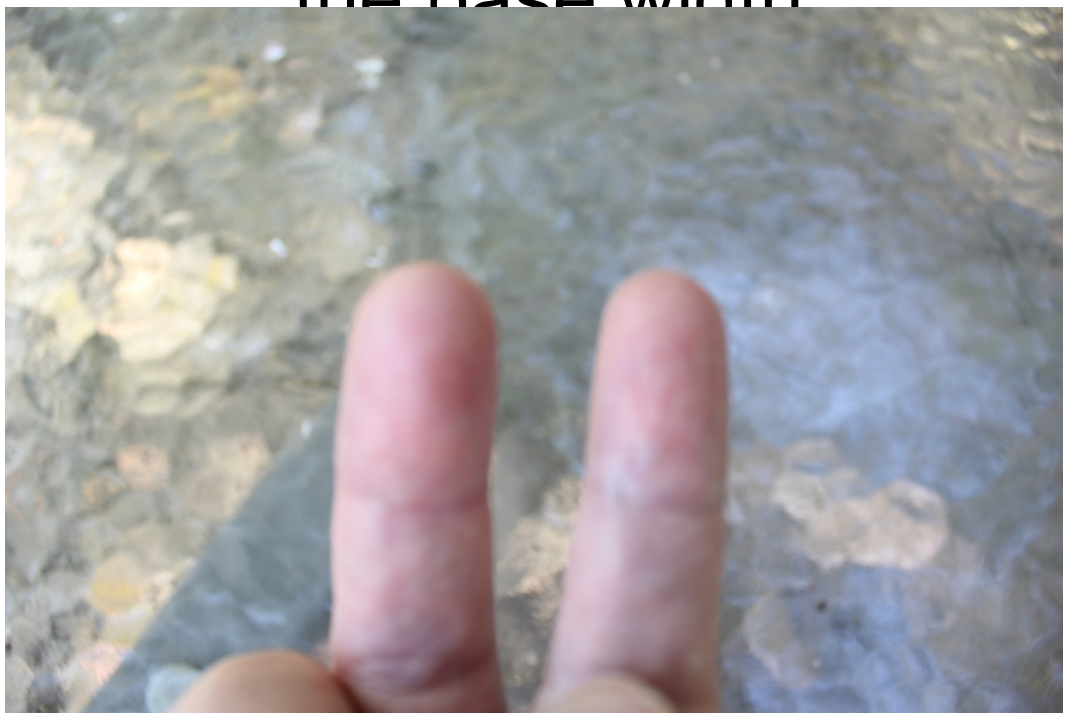
About the Speaker

- WVU, my University is a great football school now, not in 1954, but they were the only accred. WV engn. school
- MIT, taught me quick thinking in the lab and tricks, called "fundamentals" in class. I = C deltaV/delta T.
- Taught "electronics" in Army Ordinance Guided Missile School. To enter the building required a Secret Clearance.
- Joined BL because non PhD's were doing interesting things.

Point Contact, uWave Transistors, and PNPNs

- In 1961, the Army sent me on an observation visit to Reading WE and to Philco in Philadelphia.
- I saw how 2N110 transistors were made by hand.
- I also attended ISSCC and saw a >1GHz amplifier flat to 0.5 dB over 70 MHz for MAR
- I also saw at ISSCC a report about a PNPN, the size of a pea (TO5 can) that could switch 40 Amps from 400V in 100 ns. Milt Embree designed and demonstrated a stacked circuit suitable for radar pulses.

Illustration of Point Contact Fabrication
Two fine wires (~2mils. each) are seen through a microscope and moved by hand (with tweezers)to a wire width apart, defining the base width



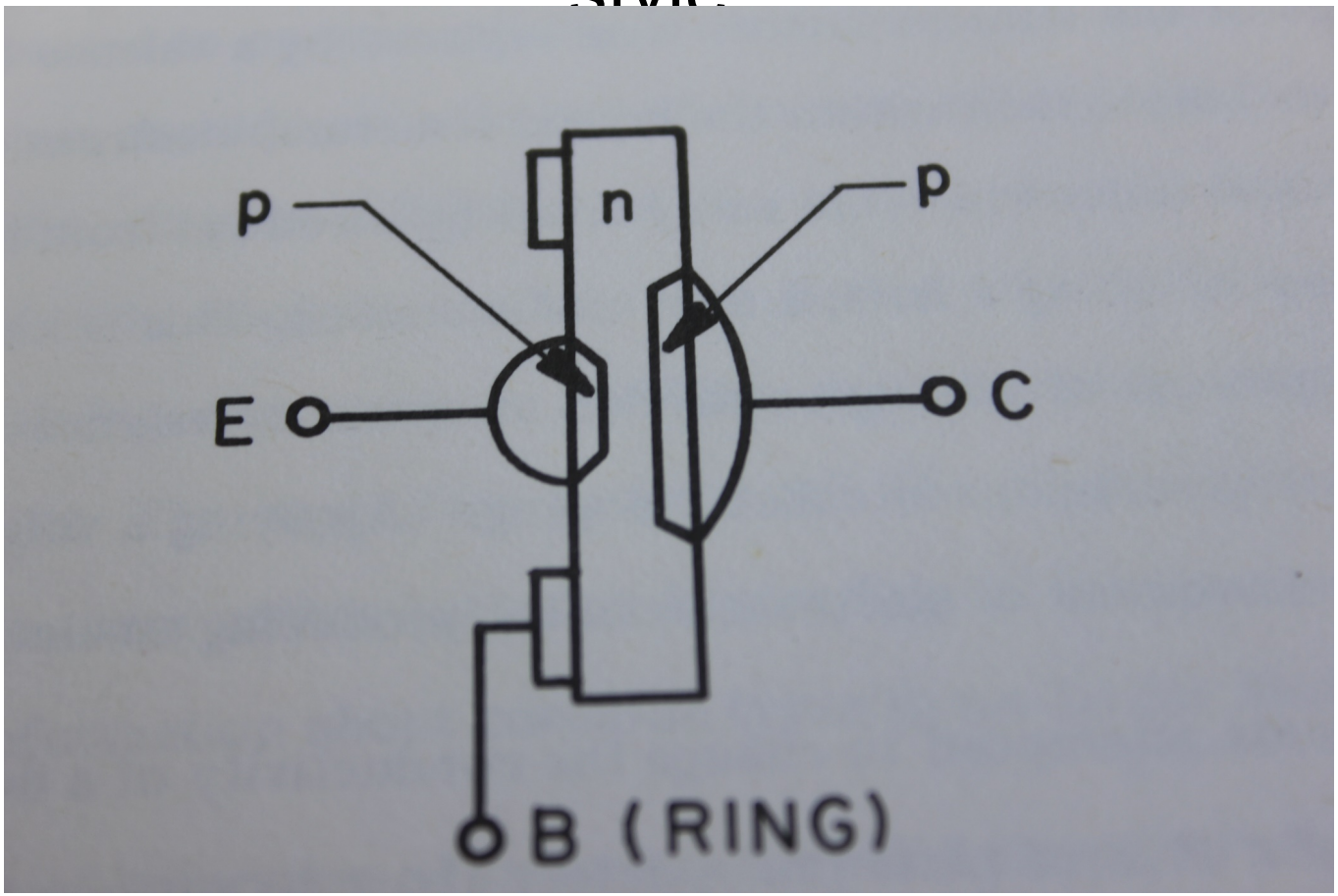
Shop floor where 2N110s were adjusted

contaminating the products.

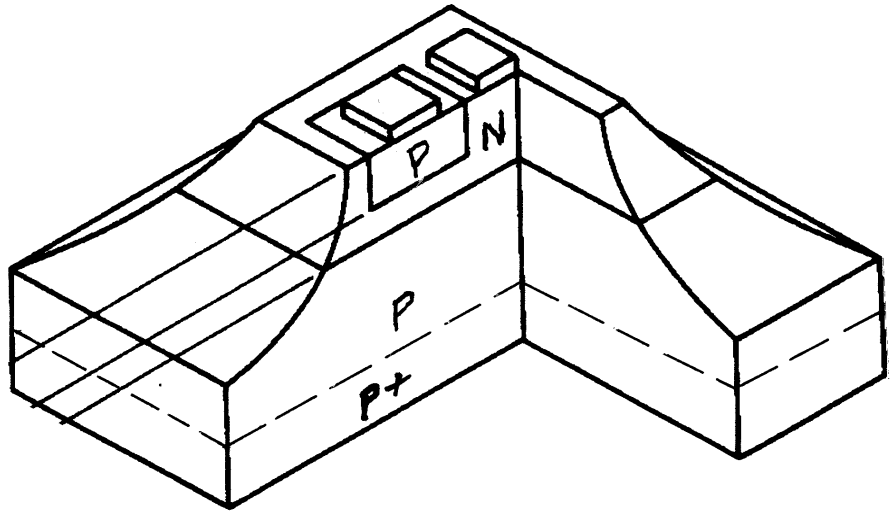
Courtesy of Milton L. Embree

Western Electric employed great numbers of women in jobs that required manual dexterity. As time went on, many

PNP Germanium Junction Transistor, Philco style



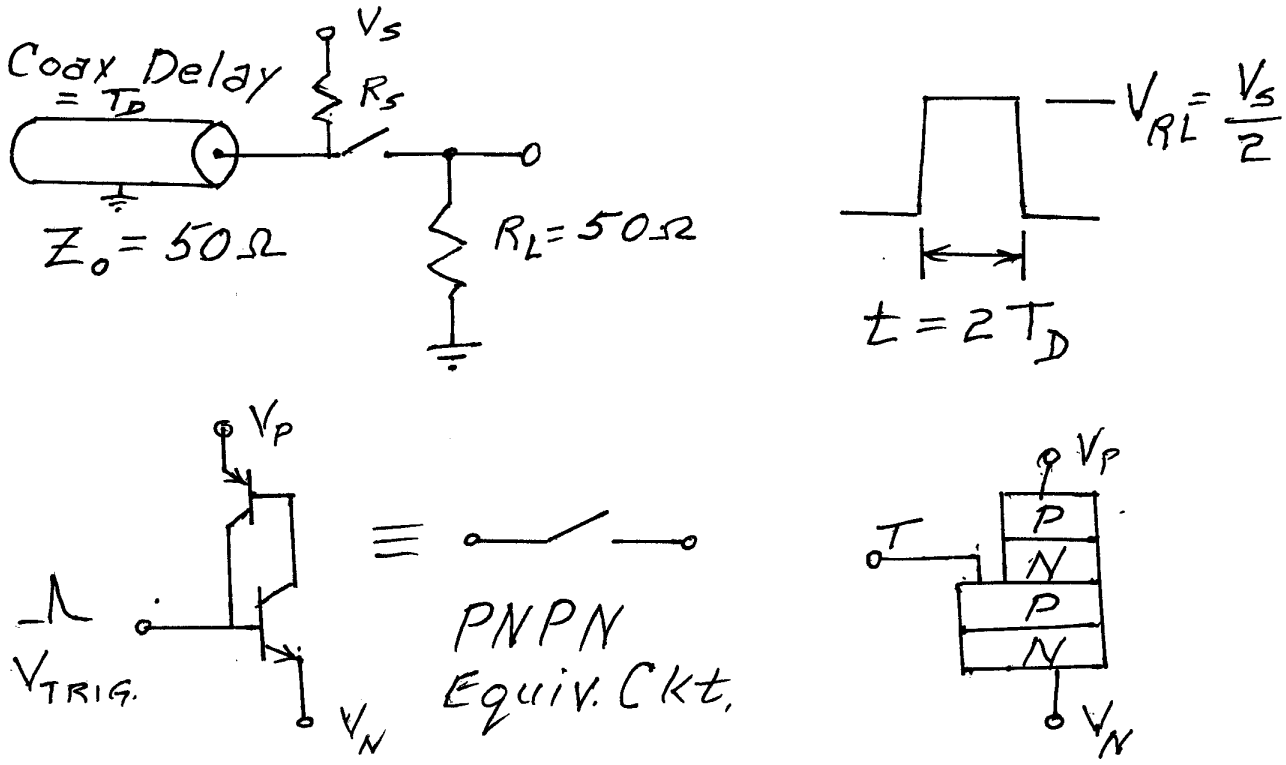
3 GHz fT germanium diffused base trans., illustration



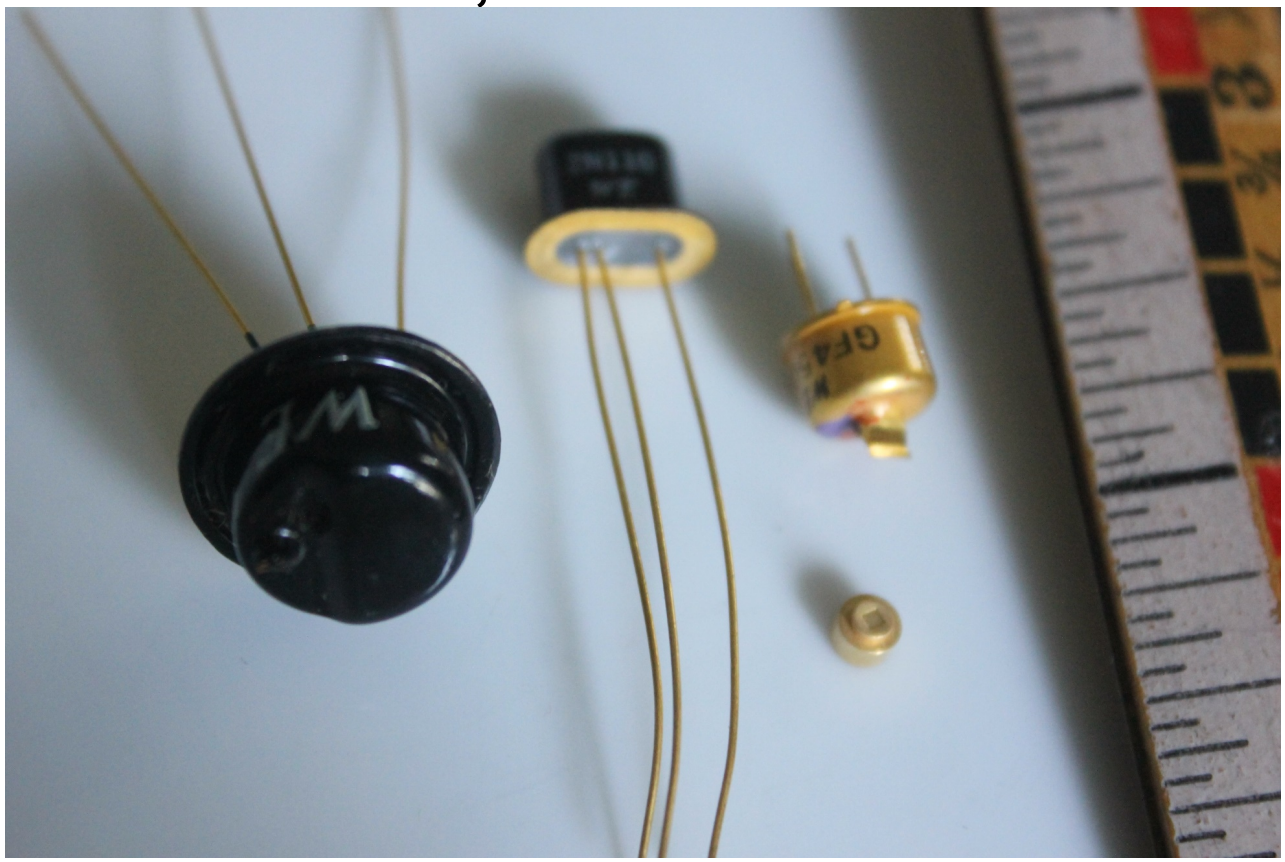
PNPN Transistor for Military Radar Driver

- A PNPN switch is modeled very accurately with an NPN transistor in com. emitter to grd. The NPN col. drives a PNP transistor base. (Next slide.) The emitter of the PNP is connected to the positive voltage which is to be switched. The PNP col. drives the NPN base, making it a regenerative switch.
- The first demonstrated devices carried 40 Amps & held off 400 Volts in a TO5 can (with heat sink)
- Milt Embree, at ISSCC, showed a stacked circuit.

PNPN, a fast, high current switch for radar



Military Packages, incl. 2N110, TO5, ½ Watt Trans., and Microwave Diode



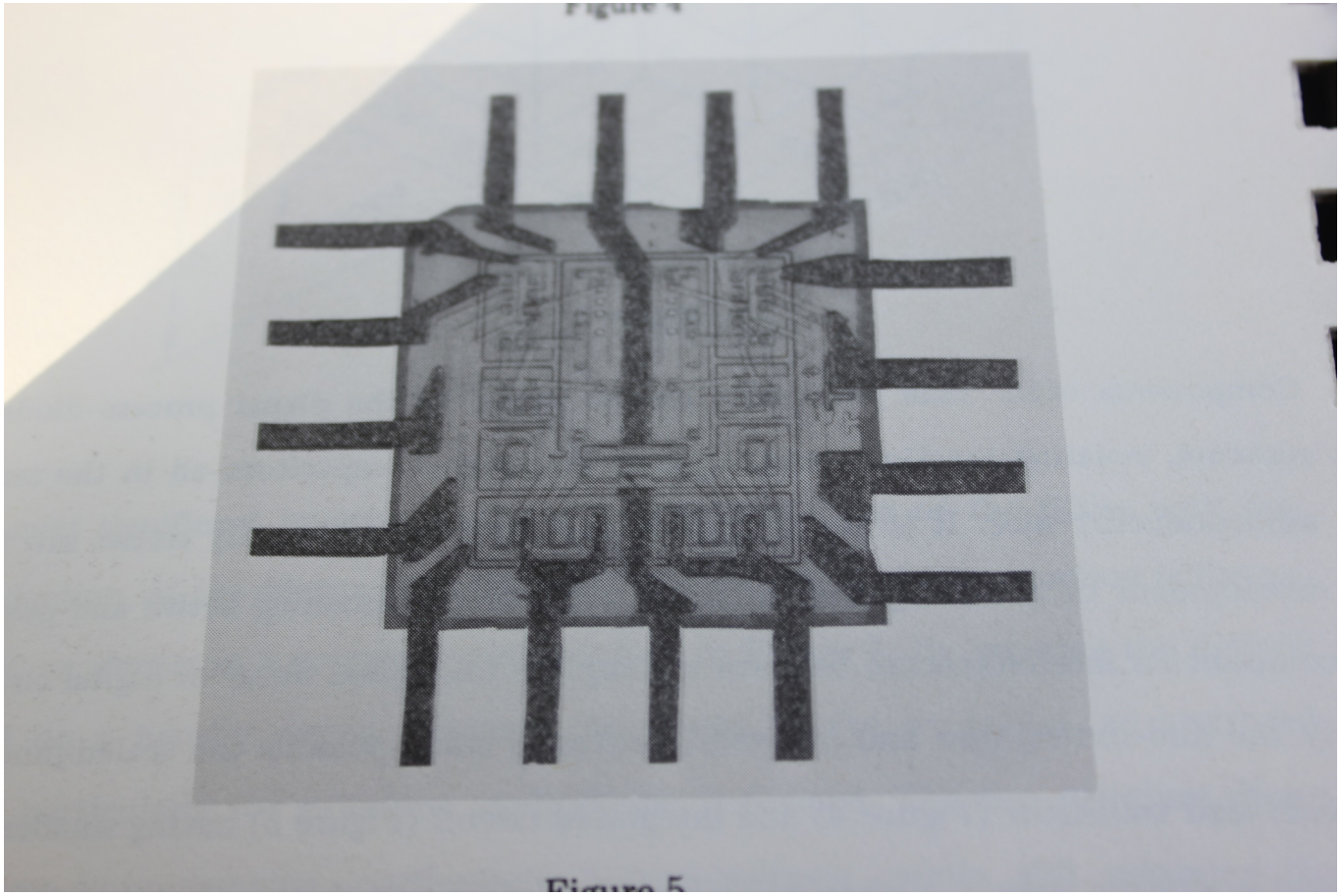
A Little History of PA Labs

- Transistor phenomenon invented in MH 1947
- First commercial transistors manufactured in 1948 in a basement on Hamilton Blvd.
- AL was doing a fine job making military devices, but the US Military demanded a split
- 1952 Reading WE was started in an old knitting mill next to a battery plant.
- 1958 Reading Bell Labs was started by importing 17 process and application MTS from AL

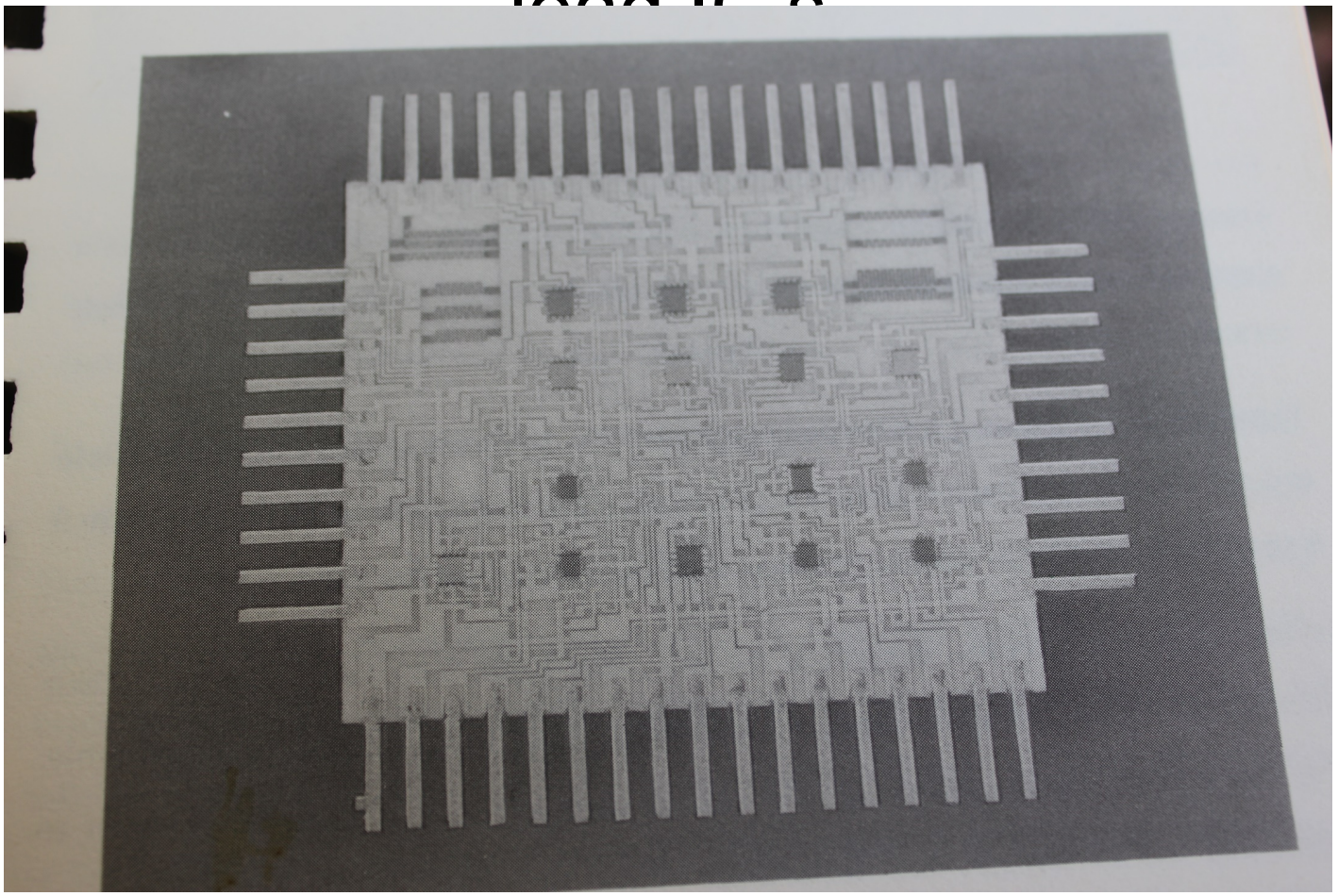
More History

- During the 1960s, Reading was designing state of the art, reliable, tran. and diodes for the mil.
- AL was concentrating on diffused base NPN silicon transistors, and diodes, for the Bell System with fTs of 200 to 900 MHz and BVceo's of 30V.
- In 1974 AL listed 104 Al packaged Bell Sys. trans. and 198 Bell Sys. diodes (transferred to RD)
- By 1970 AL had also made several small scale ICs, with beam leads, and a few linear ICs.

AL Beam Leaded IC's (Jim Early)



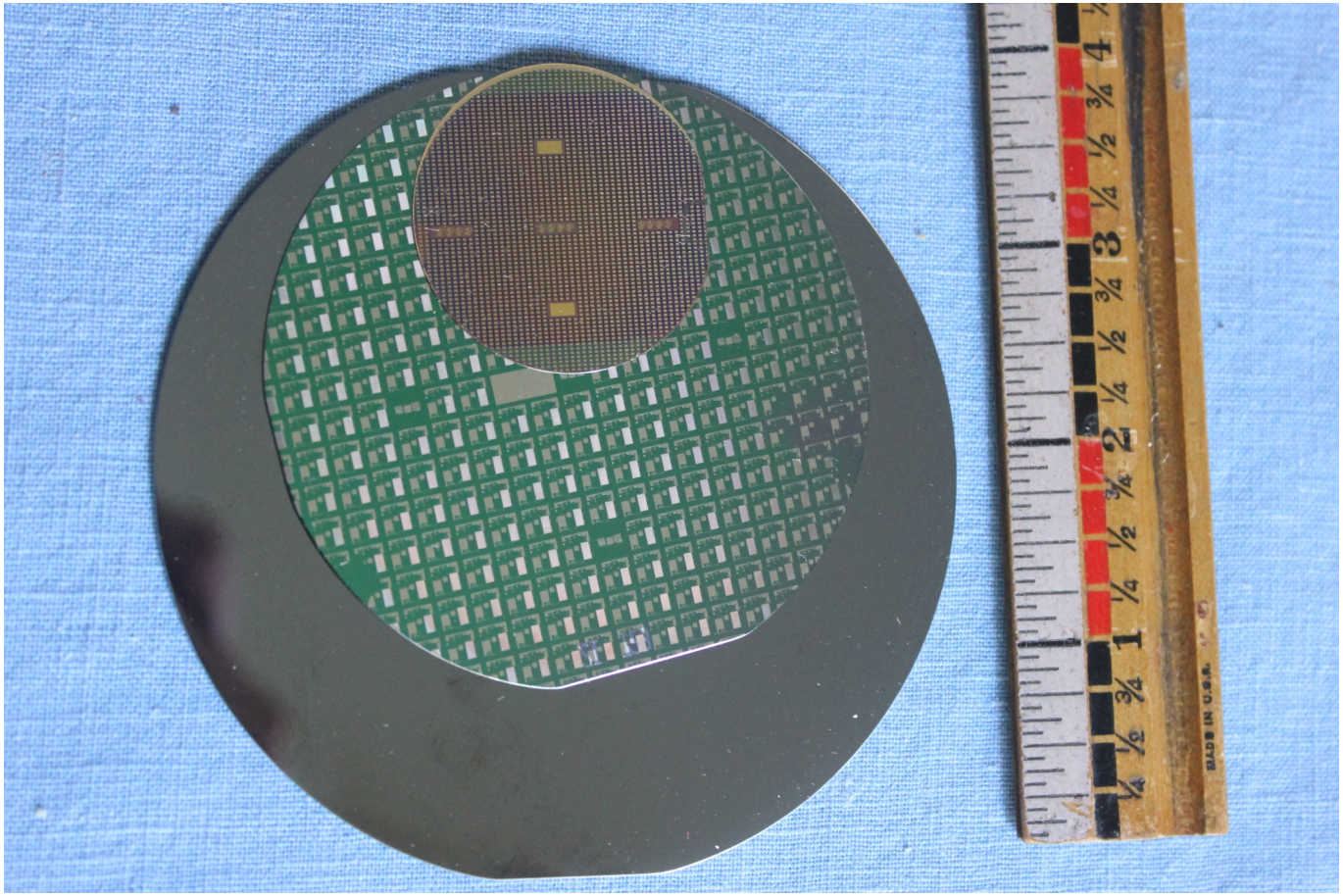
AL Larger Scale Switching “ICs“ using beam lead IC’s



Picturephone © Comes to RD in 1967

- Military business virtually stopped in 1966 and Reading was left with AT&T diodes
- Dir. Ekstrand (BSEE) argued for and got the entire Picturephone © job, with high risk, huge reward in 1967. This job included the following innovations.
- Largest switching IC in AT&T with 40 gates on one square mm. Accepted at ISSCC.
- Crystal Osc. (my first patent) and 4-pole 100 KHz filter IC, computer trimmed, were two analog IC's.
- (Not bipolar) First silicon target for picture detection.

Growth in Slice Size During the 70s



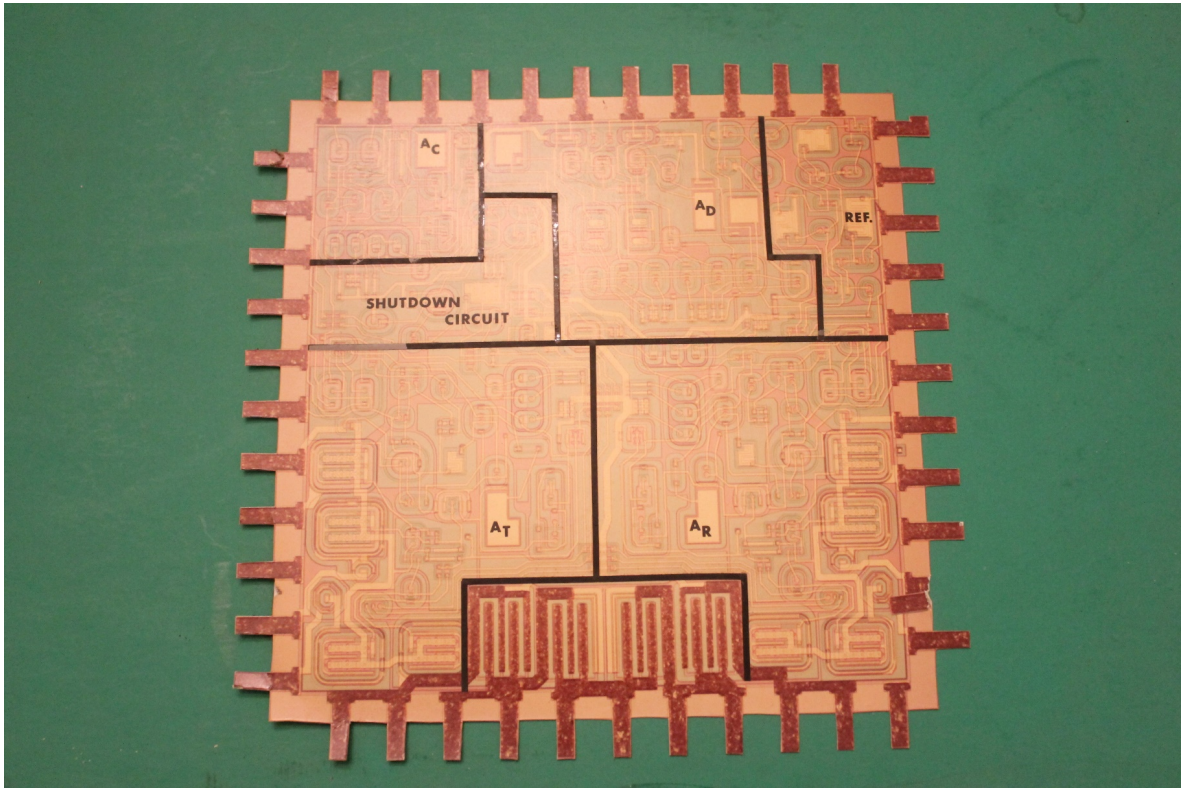
Bipolar Analog Circuit Design Blossoms

- Picturephone © was a technical breakthrough and a market failure, with few sold
- AL took over the switching and memory market
- RD/HO started the Op Amp Task Force and raised IC production from thousands to millions.
- In 1975 RD/HO presented to ISSCC a High Slew Rate Op Amp (1000V/us) on CBIC LV.
- By 1980 RD was bipolar LSI analog/digital with Subscriber Line Interface and Telephone Dial ICs

Subscriber Line Interface Challenges

- SLI or Line Feed Circuit replaces a baseball sized transformer with a 2 X 1 inch ceramic and a couple of external resistors. Mundane?
- Must supply a precision IV output characteristic
- Must detect up to 50 kHz differential signal while rejecting 60dB com. mode 60 Hz (start of e-mail)
- Must withstand a direct lightning hit outside the surge protector
- Must supply 100 mA and withstand dir. short to gnd.

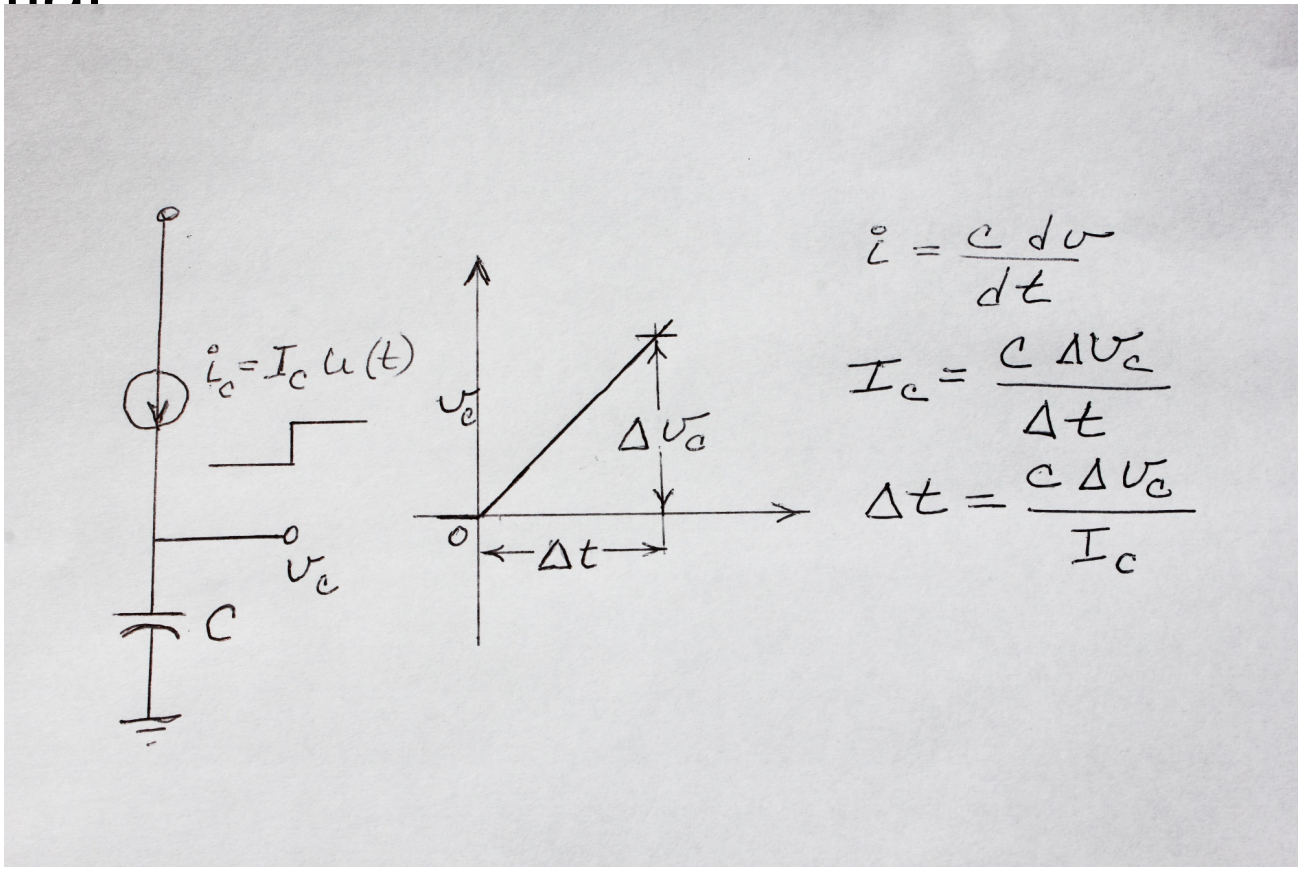
Subscriber Line Interface Output IC on 90V CBIC with 100 mA protected OpAmps



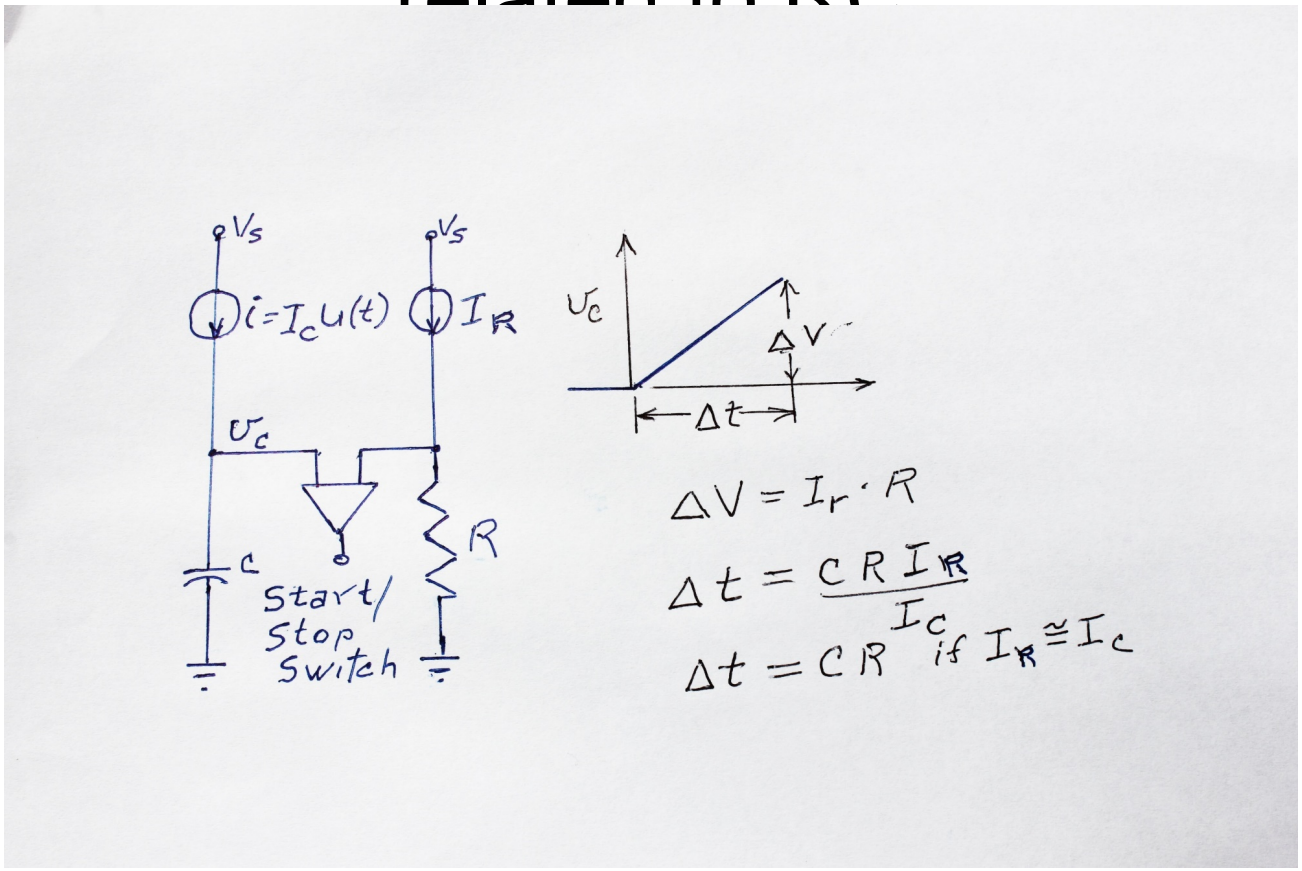
How I designed a precision osc. circuit for dial chip

- 1. Define the guaranteed and measured (at room temperature) tests exactly.
- 2. Examine the raw material, the active and passive variations with processing, voltage, temp. and time
- 3. Exploit any feature that will help meet the tested and "guaranteed" specs.
- The requirement is 160 kHz square wave +/-- 2% for IC process var., time, and temp. of –40C to +85C
- Have trim-able "fixed" R&C and matched currents.

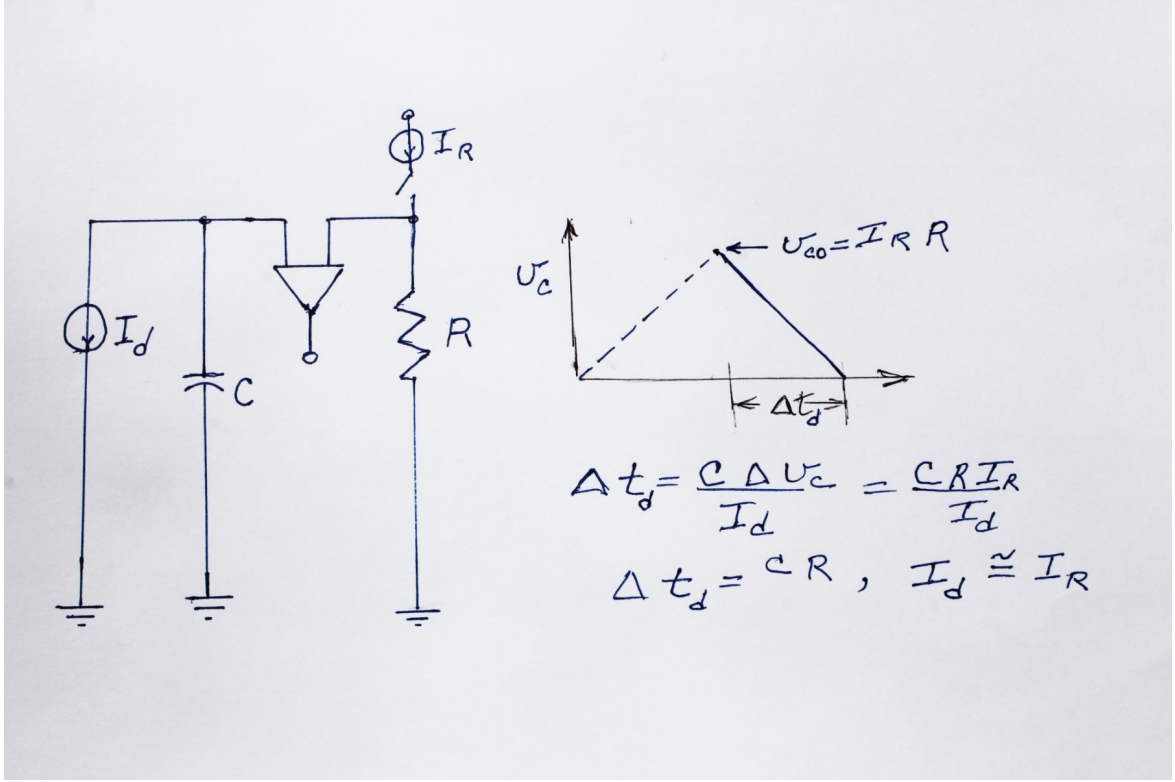
Wave shape of voltage on a capacitor charging with step function of current is a straight line, not an exponential



Comparing the dynamic voltage on the capacitor to a fixed voltage (I_R X R) gives a time period related to RC



The dynamic capacitor voltage (= I_R X R) is ramped down with an equal current to give an equal period. The total switching times of the comparator is less than 0.5% period



Why have technical conferences?

- Technical conferences provide information that is timely, vetted, and extensive, *and they're fun*, vs. journals which are published a year later
- vs. universities which are premier trainer of students on how to solve problems
- vs. intra-company presentations, restricted

BCTM (Bipolar/BiCMOS Circuits and Technology Meeting), a unique bipolar conf. started in 1986, by John Shier and still viable in 2016

- Supported by engineers from Allentown and Reading BL/ WE, who were Tech. Com. Members
- In particular Ken Sodomsky was on 2nd year Organizing Com. and was a Keynote Speaker, Yih-Feng Chyan was Gen. Chair 2007, Tom Krutsick was on the Power-Devices Subcom. , Paul Davis has attended 28 BCTM's and was on Tech./Exec. Com. > 20 years.

John Shier on the right, and Ken Sodomsky

Summarizing Origination in 1986

- Motivation of start was the loss of bipolar exposure, especially ISSCC
- Goal to establish a “bipolar conference”
- Technique was to gather an elite committee. Received member-list help from EDS, and IEEE Technical sponsorship from a local chapter
- Seed money from Com. Mem. employers
- Attendance of 400, “good papers”, and $17 k surplus, which helped kick start BCTM in 1987

BCTM Debate Between Bipolar and CMOS, 1996,
Asad Abidi, UCLA and Paul Davis, Bell Labs

BCTM 1997 Celebration of 50th Anniversary of Invention of the Transistor, "Bipolar, of Course"

J. Kilby, R. [illegible], T. Sakai

Thank you for listening.

- These slides were presented at the LVSSCS meeting, Oct. 20, 2016. They are reproduced here with minor corrections and the addition of a few slides concerning a BCTM talk which I gave on Sept. 26, 2016. I apologize, but BCTM (history) slides were not shown Oct. 20, because of a self imposed lack of time.