Oral-History:Richard Koch

About Richard Koch

Richard Koch was the engineer at Regency Electronics who headed the design of the first transistorized radio, the TR-1, introduced in 1954. Born in 1922 in Denver, Colorado, Koch was the son of a power lineman; he was destined for engineering from a young age, although he briefly flirted with chemistry. He attended Cornell University for his BSEE degree, but his pursuit of a Ph.D. at Harvard was interrupted by service in the Navy during World War II. After the war, he started his own businesses and was recruited to Regency by a Navy buddy. In the interview, he describes the genesis of the TR-1, from a semi-secret meeting with Texas Instruments (who would supply the transistors) in July 1954, through a breakneck development process leading up to the Christmas season of that year, to its success in the marketplace. He points to a large number of innovations that had to be made on the fly, including the dip soldering of the circuit board, something competitors doubted could be done. Koch also talks about the portable TR6 introduced in late 1955, then quitting Regency and moving back to Denver in 1956, where he worked at Martin. He also took over the family business of making banana plugs, leaving Martin in 1960 to focus on his business. Koch later worked again with Regency and was a consultant until 1962, then worked as VP of Engineering then product design engineer. He officially retired from Regency in the summer of 1984, but he remained a consultant as of this interview.

About the Interview

RICHARD KOCH: An Interview Conducted by Michael Wolff, IEEE History Center, 10 December 1984

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Interview

Interview: Richard Koch

Interviewer: Michael Wolff

Date: 10 December 1984

Place: Regency Electronics in Indianapolis, Indiana

Regency Electronics and I.D.E.A.

Wolff:

We're here to talk about the Regency radio (/Radio). We are at Regency Electronics now, and you have retired from it. You are now a consultant.

Koch:

Correct.

Wolff:

What kind of business does Regency Electronics do?

Koch:

This plant is involved in cable units that go into the home between the cable and TV set. We sell to the cable companies. We're also in the satellite receiver business. We have a line of dishes. The other main endeavor here is load management equipment for the firefighters, which turns on and off major systems within consumers' homes such as hot water heaters, circulating pumps for swimming pools, air conditioners, etc. We have a communication division in Florida and another division in Wichita that is in high-level aircraft electronic test equipment. Another division is in Las Vegas, there is a plant in the Philippines, and what else I don't know.

Wolff:

Is this still a division of this I.D.E.A.? Is I.D.E.A. still in existence?

Koch:

Industrial Development Engineering Associates (I.D.E.A.) was formed in a basement here in Indianapolis. Once they got out of the basement, this is our fourth facility of the main operation.

Wolff:

In whose basement was it formed?

Koch:

Joe Weaver is his name. He is still on the Board of Directors and has an operation here making printed circuit boards. He's a mechanical and chemical engineer by degree. Three people from RCA (/RCA_(Radio_Corporation_of_America)) formed this company. They were all in the 16-mm motion picture sound projector area of RCA (/RCA_(Radio_Corporation_of_America)) here in town. Joe had an idea on how the projector should be built mechanically. RCA (/RCA_(Radio_Corporation_of_America)) threw the idea out the window, so he started on it in his basement. He took in another man who was electrical to go into the motor drive system and evaluate motors and whatnot. They took in a third individual who was in the sound section of RCA (/RCA_(Radio_Corporation_of_America)), and he was my roommate in the Navy for about a year and that's how I happened to wind up here.

Wolff:

I see.

Koch:

Three of them were involved in it right near the end of the war. After the war was over it expanded. Ed Tudor (/Oral-History:Edward_Tudor), who became president, came into the organization at that point.

Wolff:

After World War II.

Koch:

Yes. As a matter of fact the first time I saw him he walked in the door in uniform. I think his association was probably with the fellow who was my roommate, George Fathauer. Ed Tudor (/Oral-History:Edward_Tudor) and George Fathauer probably knew one another from the University of Illinois.

Wolff:

George Fathauer was your roommate in the Navy.

Koch:

Yes. We were in an Admiral's staff that was going to lead the invasion into Japan mainland. Regency was a trademark for certain products of I.D.E.A. They decided to go public at some point '56 and before '60. They wanted to get electronics into the name, so they just changed the name of the corporation from I.D.E.A. to Regency Electronics. They had two subsidiary companies. One was Radio Apparatus Corporation, which made police band radios (/Radio). It was the same people, but they didn't want to bring it into I.D.E.A. because they didn't know the legal liabilities of having that type of a product. Their more advanced line became the Monitoradio trademark. They merged the two operations under I.D.E.A. in the mid-'50s. Then they formed Builders Incorporated, which built the original building on this property. At that time they were located in downtown Indianapolis. They also built some homes and things. That was operated by Joe Weaver.

Wolff:

Is there an I.D.E.A. now?

Koch:

No. It has completely disappeared by virtue of I.D.E.A. becoming Regency Electronics. It was just a name change.

Wolff:

I see. Regency Electronics is a publicly owned company. One thing I want to get before I leave is their latest annual report or brochure. I assume someone has got that around.

Koch:

They should have some.

Education, WWII & Early Work at I.D.E.A.

Wolff:

Good. Tell me about your background and the circumstances under which you joined Regency. You were born when and where?

Koch:

I was born in 1922 in Denver, Colorado. I was raised in Colorado and went to Cornell University for my BSEE degree. The draft board kept me in school, and I graduated in February of '44. I have a scholarship as a candidate for a Ph.D. at Harvard and I lasted about three months before the big finger pointed at me, "We need you."

Wolff:

You were at Harvard when you were drafted in the Navy.

Koch:

Yes. I applied for a commission and got it, and went to Fort Skylar for officers' training. You know where that is?

Wolff:

No, I don't.

Koch:

It's out on Long Island. It may not exist anymore, but that was the location of the training school. I spent one month back at Harvard again in pre-radar (/Radar), then went through radar (/Radar) school at MIT — sonar and countermeasures. Then I was kept at another school that didn't even exist. It was just getting ready to be set up. I think most of this was a stall, because it took forever from the time I got my commission to the time I reported to duty. I think I was scheduled to go on that staff from day one. I was sent to a temporary duty station in Rhode Island. Typically it was place where people were sent for a week or two weeks while were waiting for their ships to come in at New York or Philadelphia. However, I was there for two and a half months.

I was already supposed to go to Task Force 69, which was hush-hush. I didn't even know its purpose. We evaluated radar (/Radar) equipment from the standpoint of early detection of kamikazes such as from antenna patterns. There was no paperwork involved other than what we had to do to prepare evaluation tests. Reports were verbal. "Don't work." That's the way it went to Washington: "Don't work. Forget it." The Admiral that ran that was in charge of Battleship Squadron 3 out in the Pacific that cleaned up what was left of the Japanese Navy. He was sent to Casco Bay, Maine to form this group that was going to prepare the invasion into the mainland of Japan, which was scheduled for November. The bomb was dropped in August.

I think I'd have a 50/50 chance of being here if we'd gone into Japan, because it would have been bloody. George Fathauer joined that task force a month or so after I did, and once we got our flagship, three of us shared a stateroom for four. George and I got involved in a project aboard ship with electronic organs. I was due to get out first, and he was in a hurry to get out so he asked if we could swap. I said, "Sure, I have no place to go." He wanted to get here because of I.D.E.A. We swapped dates, and when I got out I stopped off here for a week, still in uniform, and started on a project for them. Besides the motion picture thing, in order to support themselves they were doing consulting work. The first project in which I got involved was calibrating a piece of equipment they built. How long does it take for a stick of dynamite to explode from this end to this end? I had the job of calibrating that thing.

Wolff:

What do you mean by "explode from this end to this end"?

Koch:

Stick a cap in one end of a dynamite stick with a wire going through it. How long does it take for that explosion to propagate from one end to the other end? The concept was that two pieces of fine wire that went through there broke a circuit that started charging the capacitor. And when this went, it stopped charging. By measuring the voltage that is on the capacitor and knowing the time constants involved, that's how long it took to get from point A to point B.

Wolff:

Did you go to Indianapolis with the intention of going to work for Regency?

Koch:

No, I just came through here as a visit on my way home from the Navy. They had some things for me to do, so I went in the consulting business. I went home, got back into civilian clothes and came back to work on some of these projects. This was 1946 and early '47. I'll be honest about this. George and I had a personality conflict. I found out that I could work with George but not for him, so I left in February or March of '47. In December of '49 — I believe it was after Christmas — Joe Weaver called me up and said, "We need some help. Can you come back here and help us? We know your problem with George. You will not be responsible to George alone but to management." I came in February of '50, and they asked me to get on the payroll in '51. George was going to be there only another month or two at that point. What they brought me back on was a new model of TV boosters. That was their big business then. They had better than 50 percent of the market. We got that into production. We were in hi-fi in the early '50s and the Monitoradio business. Those were the major products.

Childhood

Wolff:

Let me go back and then we'll move forward again. Were you always interested in electronics when you were a boy?

Koch:

I had my first lineman's belt when I was 6 or 8 years old.

Wolff:

What is a lineman's belt?

Koch:

That's what a lineman wears when he climbs up a pole and straps it around the pole.

Wolff:

A telephone lineman.

Koch:

Well, this was power. When I was a boy my dad was the head of a distribution department of a public service company. It was a Denver Area distribution department, Public Service Company Colorado. He later became a vice president.

Wolff:

Did his work inspire you?

Koch:

Yes. I lived out of a junk box. I was a ham operator since '37 or '38. I waivered once. As a junior in high school, I got so interested in chemistry I thought I would get into that. Then I got sensible. I don't have the memory for the chemical world.

Wolff:

You were always involved with electronics and ham radio (/Radio) and things like that.

Koch:

Yes. I had a slide rule when I was a kid.

Wolff:

When you first came passing through Indianapolis, they offered you a job consulting to work on this dynamite calibration?

Koch:

Yes. In order to calibrate it I had to buy about $3 worth of parts. Made a delay line.

Wolff:

When did you officially become an employee of Regency?

Koch:

January 1st, 1951 was when I became an employee on the payroll. I worked for them almost all of '50 as a consultant. That was my second tour of duty as a consultant and my first as an employee. In '49 I incorporated a business that made banana plugs, panel jacks and test leads.

Wolff:

Where?

Koch:

In Denver, in my dad's basement.

Wolff:

This was after you had quit the first time.

Koch:

Yes. I stayed in the consulting business all the way up to the time that I came back here and became an employee in '51. My most interesting client was a retired physics professor from Johns Hopkins. When he saw me, a mere kid, walk in his office to do a job for him that I had contracted by telephone through my patent attorney — he liked to drop dead when he saw a kid walk in as a consultant. You could imagine.

Wolff:

What were you asked to do for him?

Koch:

He was filing a patent for a uranium ore sorter. The concept was that the radiation coming off the ore is measured, and if it was none it was junk, and if it was a high count it was high grade. Then there was a million grade, low grade or however one wanted to split it up. The equipment had a conveyor that went down to where a trap door would open up so it would go into the proper grade pile. That was the invention. He needed somebody to draw up the schematics of a feasible working operation. I gave him two. One was electrical-mechanical and the other one was hydraulically operated rather than with motors. The next job I did for him that was major was a continuous logging system of an oil well operation. Whether there was any petroleum was what had to be answered by the logging.

Regency in the Early 1950s

Wolff:

Do you remember what your salary was when you came back to Regency on January 1st, 1951 as an employee? That would be interesting to know.

Koch:

I would guess $800 a month, but I don't remember and I don't think I have the records to say one way or another.

Wolff:

That's all right. About how many professional engineers were at Regency then? Do you know?

Koch:

It was different in '50 than in '51. One engineer over at RCA (/RCA_(Radio_Corporation_of_America)) joined the staff effectively on the same day I did in '51. In '50 we probably had six or seven engineers. That was when we were downtown.

Wolff:

Then in 1951 when you came back, how much had the engineering department grown?

Koch:

There were about eight engineers.

Wolff:

All right. It was a small department. Do you know about how many engineers they have now?

Koch:

I'd have to walk down the hall and count them. I think the top number of engineers that have been here has been probably around twenty-five. I don't know how many we have today. I think it's less than that.

Wolff:

That's good enough. I.D.E.A. was described by Ross Smith as an aggressive company since its founding in September of 1945. In what way was it aggressive?

Koch:

We always looked for new things to do. About 1953 we acquired a positive carbon resistor (/Resistor) manufacturing operation out of Chicago and moved it to Puerto Rico. Then we moved it back, because although the labor was excellent we did not have enough technical help down there. Technically we needed to improve the line. Joe Weaver and John Pies made a real product out of it. When we did the transistor (/Transistors) radio (/Radio) — I should say transistorized (/Transistors) — we contracted for a million dollars' worth of transistors (/Transistors) from Texas Instruments (TI). We were having financial problems, so to pay off part of that bill, TI took the positive carbon business because they were in components. The number two man was John Pies. Joe Weaver was number one since he started it. Pies traded that operation with TI because he knew that business.

Wolff:

The positive carbon business was sold to TI to pay for the transistors (/Transistors)?

Koch:

Yes, in exchange for part of the transistors (/Transistors) I think. I don't know whether that should be published or not. Then eventually they got out of that business.

Wolff:

When he calls Regency an aggressive company did he mean it was aggressive because they were always looking for new opportunities in electronics? I guess the TV boosters are an example.

Koch:

That's right.

Wolff:

Okay.

Koch:

We private-labeled some phonograph/radio (/Radio) combination consoles back in '46 or '47 to a local distributor here in town that couldn't get merchandise. It was right after the war and nobody had merchandise. They have been into a whole bunch of things. "Aggressive" is Ross's term, but they are always looking for something new. You have to.

1954 Transistorized Radio Meeting with TI

Wolff:

All right. Now tell me about the transistorized (/Transistors) radio (/Radio) project. When did you first hear of it and get involved in it?

Koch:

We had designed and built a UHF converter with a minimal amount of parts and we were having trouble down South with them conking out. The chief engineer at that time was Ray Morris. He said, "You and I are getting on an airplane and we're going down to Texas to change the diodes (/Diode) in them." The diodes (/Diode) were giving out.

Wolff:

Wait. Why did you go to Texas?

Koch:

The reason we got on an airplane to go to Texas was to take these radios (/Radio) that were in distributors' places and change the diodes (/Diode) in them. When we got on the airplane out of Chicago he said, "The real reason we're going is to see TI about this transistor (/Transistors) radio (/Radio)."

Wolff:

Was that the first you had heard of it?

Koch:

That was the first I had heard of it. I had never touched a transistor (/Transistors) before in my life, or used one. We repaired or modified some converters in Houston and a couple of other places and then we went into Dallas and sat down with Pat Haggerty and Roger Webster. I think there were only the four of us.

Wolff:

Who is Ray Morris?

Koch:

He was chief engineer at Regency. I think he came from a facility that the Army has at Red Bank.

Wolff:

Army Signal Corps Laboratories.

Koch:

Yes. We had done some contracting work for the government and they got him in here from sales standpoint. I believe he replaced Fathauer as chief engineer. That was political. He had been in the coil business with Coilcraft in Chicago.

Wolff:

Why did he pick you to go with him?

Koch:

I can't answer that.

Wolff:

Is he still around?

Koch:

Probably. If he is still around, he's here in town.

Wolff:

He is someone I should call sometime.

Koch:

To answer your question of why he picked me, probably of the people that were there at the time I was the least afraid of anything new. I was probably the most likely candidate within the company. It was essentially a one-man project.

Wolff:

You sat down at the table at Dallas. What happened there? I would also be interested in your reaction to Haggerty (/Patrick_E._Haggerty) and Webster.

Koch:

As I recall it, they had built two breadboards — one out of silicon and one out of germanium. Silicon was out of sight price-wise. They had figured that they could not market anything in a radio (/Radio) for under a hundred dollars, and they didn't think the market would stand for it. My recollection was — and I think theirs will be different — that the top price they set was $79.95. If it was over that it was a no-go. We were in the consumer high-mass production business, and that's how they happened to be interested in us. Our thing was high production. They had a chicken and the egg situation. Unless there was a market for a big volume of transistors (/Transistors) they couldn't get the price down. I'm sure they lost money on the early production, until they developed the mass-production technique.

Wolff:

I see. What was the main product that you were putting in mass production at that time of that meeting? Was that meeting in 1954?

Koch:

That was about the tail end of the booster market — it was tapering off because of new improved front ends and hi-fi — and the monitor business, which was not a really high volume.

Wolff:

You think they turned to you because of the mass production capabilities of the company. What happened at the meeting?

Koch:

They presented the breadboard. It was a six-transistor (/Transistors).

Wolff:

I should interrupt you. Before that, did Morris tell you anything else about the project while you were on the airplane?

Koch:

Just that we were going to talk to TI about building a transistorized (/Transistors) radio (/Radio). That's all he told me. He said it was hush-hush up to that point. That was the first I knew of it.

Wolff:

You knew what transistors (/Transistors) were.

Koch:

I knew what they were.

Wolff:

Did you talk about the project any more than that while on the airplane?

Koch:

Not really. We didn't know what to talk about.

Wolff:

Okay. Then you come into this conference room with Haggerty (/Patrick_E._Haggerty) and Webster and they showed you breadboards?

Koch:

They showed us a breadboard. It was working. It had six transistors (/Transistors) in it. I looked over their circuitry. They had an oscillator, a mixer, two IFs, a detector and audio. Those were the six transistors (/Transistors). What they wanted us to do was package it and take the nickels out of it.

Wolff:

Is that what they told you? How did they present the problem to you? What did they say after they said, "Good morning, gentlemen"?

Koch:

They said, "This is what we want to do. We want to make transistors (/Transistors). We don't have the expertise." Basically they admitted that they wanted to sell it for under $100.

Wolff:

In other words they wanted to make transistorized (/Transistors) radios (/Radio).

Koch:

They wanted to make transistors (/Transistors). They figured they couldn't make transistorized (/Transistors) radios (/Radio) at a profit at what the market would bear.

Wolff:

Therefore they said to you, "We want you to do this."

Koch:

Yes. Our job was to take their circuit and take the money out of it and put it in a package that would fit in a shirt pocket. That was the goal.

Wolff:

That was the goal. Did they speak specifically about the shirt pocket?

Koch:

Yes. It had to be something new and different. It couldn't be a tube-sized portable like Raytheon (/Raytheon) produced. It had to have that miniaturized gimmick. I don't know that they used that terminology.

Wolff:

Do you recall them using the words "take the nickels out of this"?

Koch:

Well, we had to do it economically, and they didn't see way of doing it.

Wolff:

Right. So that was your language.

Koch:

Right there I said, "Okay. Let's see if we can replace the detector with a diode (/Diode)." Roger and I went down to his lab and he took it out and put a diode (/Diode) in and the performance was the same. Then we went back to the conference room. Now it's five transistors (/Transistors). They wanted $12.50 for the kit of six transistors (/Transistors) – what it would cost us. That took $2 out of it. Haggerty (/Patrick_E._Haggerty) said, "Oh no. We grade these. They are basically all the same process, and we grade them. The best ones become the mixers; the worst ones become the detectors. It only takes a little bit out." We got a 10-cent or 15-cent diode (/Diode) to put in there instead of a 50-cent transistor (/Transistors). They had their business discussions and we headed back home.

Wolff:

Before we talk about heading back.

Koch:

Incidentally, Roger was the one who designed the breadboards. My opinion of him is topnotch.

Wolff:

The meeting was basically the presentation of the problem and they said, "We want you to do this" and right away you demonstrated that you could reduce the six transistors (/Transistors) to five by substituting a diode (/Diode) for their detector. Is that right?

Koch:

Yes.

Wolff:

You still had to pay nearly $12.

Koch:

They did not come up with a reduced price at that point.

Wolff:

What was your reaction to Haggerty (/Patrick_E._Haggerty)? What was his role in the meeting?

Koch:

He was then president of Texas Instruments. He was a fine gentleman.

Wolff:

Do you remember him saying anything particularly memorable?

Koch:

Not particularly. No. It was too long ago.

Wolff:

Was it Haggerty (/Patrick_E._Haggerty) that laid out the problem for you?

Koch:

I think the concept of what had to be done and why we were doing it was probably laid out by Haggerty (/Patrick_E._Haggerty). There had to be meetings before that between our executive and theirs to make the arrangements that, "Yes. We'd like to take this on." The only one that can answer that is Ed Tudor, I suppose.

Wolff:

In 1980 he was vice president of AMI, Incorporated.

Koch:

I was not aware of that.

Wolff:

I imagine someone here must have his address, isn't there?

Koch:

I doubt it, unless he is still a stockholder. I can find out.

Key Innovations and Patents for TR-1

Wolff:

I'd appreciate that. There must be someone who has kept up with him. All right. Then you went back home after the meeting.

Koch:

Yes. That was July Fourth weekend.

Wolff:

What happened next?

Koch:

We brought their breadboard and schematics back and I sat down on the bench. I don't remember what IF they had in it at the time, but I tried to put some available 455 IF transformers (/Transformers) in it and couldn't get the gain. We were already beyond the cutoff. When the frequency is doubled, 6 dB is lost per stage. I tried it twice and still wound up with the 256 or whatever we put in it. Then I was driving Ray Morris home one night. He had left his car at the filling station up north, and on the way I was just rambling along and said, "You know, the currents in the mixer are the RF currents plus the oscillator currents, so if we made a converter out of that we'd get rid of one stage." And that's what we did, so we wound up using four transistors (/Transistors). That was a $10 kit.

Wolff:

Is this the concept for the single-transistor (/Transistors) oscillator/mixer circuit?

Koch:

That's correct.

Wolff:

You thought of that in the car?

Koch:

Roughly. It had probably been mulling around in the back of my head for a few hours.

Wolff:

You invented that. Is the patent in your name?

Koch:

It's in my name and assigned to Regency. The agreement with TI was that any patents that came out of this would be in the public domain in the United States, because they wanted to sell transistors (/Transistors). We collected royalties from Japan at one point.

Wolff:

I'm more concerned with the invention. I would like to get a copy of the patent. How many patents do you have altogether? Do you know?

Koch:

No.

Wolff:

Do you know in order of magnitude? Is it four or forty or four hundred?

Koch:

It's not four hundred. It's somewhere between four and forty. The last one we got was on the load management system, which is a joint patent between me and one of the other engineers here. When I was in the banana plug business I got three or four patents there.

Wolff:

I would like to get copies of the two patents for this radio (/Radio) that you invented — the transistor (/Transistors) oscillator/mixer and the biasing circuit.

Koch:

Then there was also one on the mechanical assembly.

Wolff:

Was that your patent too?

Koch:

Yes.

Wolff:

You got three patents for this?

Koch:

Yes

Wolff:

Can you find the numbers, or do you have copies of them?

Koch:

We'll try.

Wolff:

Okay. I'd appreciate that. If you don't have copies, if I get the numbers I can get copies myself.

Koch:

Our patent attorneys at one time were going to get a list of the patents that had been issued to this company.

Wolff:

I'm just interested in those three.

Koch:

I have a list, but I don't know whether it goes back that far. I've got it in my file cabinet, so I'll go back over there and look, but I'll forget so you'd better remind me.

Wolff:

The first sort of breakthrough, if you will, was the idea of the oscillator/mixer circuit combined. That got it down to four transistors (/Transistors).

Production Design for TR-1

Koch:

I came in one night to work on this thing and Ed Tudor was running a little bit shaky. My wife was there with me.

Wolff:

What was Tudor nervous about?

Koch:

He was nervous about getting there, because he couldn't see progress.

Wolff:

Was there a deadline put on you?

Koch:

We had to be on for the Christmas market, and we had to allow lead time for plastic tooling.

Wolff:

Do you remember what month it was?

Koch:

It was probably in August. He said, "What are we doing all this stuff for? We are just supposed to be packaging it and taking the money out of it." I said, "Look. There's not a single person in this plant who has ever had any experience with transistors (/Transistors). Somebody has got to get the experience. I'm getting experience. Somebody is going to have to fight these problems in production when they come up." We were in the hi-fi business and downstairs we had a demonstration room with padded walls or drapes and whatever. She said to Ed Tudor, "Why don't we go down and dance?" And that's what they did.

Wolff:

What did they do?

Koch:

Ed and my wife went down to the demonstration room and danced. She got him out of my hair. It came together.

Wolff:

When did it come together?

Koch:

It came together the tail end of October.

Wolff:

You must have been working seven days a week. Is that right?

Koch:

Just about, I would guess.

Wolff:

How many people were involved and working on it here? Was it all just you?

Koch:

I had drafting help. I did all the circuit work and the basic packaging design. The exterior appearance was done by Painter, Teague and Petertil out of Chicago. They had to go through two designs. The first one could not be made.

Wolff:

Are those individuals or is that the name of a company?

Koch:

Painter, Teague and Petertil are three individuals, and that was the name of the design company. They were industrial designers.

Wolff:

And what did they do?

Koch:

The aesthetics.

Wolff:

Of the package?

Koch:

Yes. The first basic outline they did could not be built with the requirement that it would still fit into a shirt pocket. It was impossible. I came up with a mechanical configuration that satisfied the dimensions. The tolerances in that thing were unreasonably close.

Wolff:

Like what?

Koch:

I think if any single part in that was out of tolerance, +/- 5 was typical.

Wolff:

+/- 5 what?

Koch:

Thousandths. It would not have gone together.

Wolff:

You are talking about mechanical tolerances.

Koch:

Yes, mechanical tolerances. We made the thing so that it would fit into an expensive dress shirt, but would not fit in some of the cheaper brands.

Wolff:

Were you the only one working on this?

Koch:

As I say, I had help drafting, and I had whatever mechanical help I needed at the model shop. I was the only one working on it electrically until down near the end. Then another engineer, Bob Ligget, he had helped with layout, model building and whatnot.

Patent on Oscillator/Mixer Circuit

Wolff:

Incidentally, he [Ligget] is probably responsible for getting our patent allowed. RCA (/RCA_(Radio_Corporation_of_America)) had a patent for a converter. Ours was different, but it was still a converter. The logic was that if the signal currents and the "oscillator currents," quote-unquote, are both going in the base and there is a common emitter, that is method number 1. If they both go in the matter with a common base, that's method number 2. Another is if the main oscillator currents are in the emitter in the signal in the base and vice versa. There are four configurations if you want to look at it that way.

Wolff:

This was converting what to what?

Koch:

This was converting the broadcast signal to IF. Out of the four configurations, RCA (/RCA_(Radio_Corporation_of_America)) was the first one, ours was the second, the third one became a patent of somebody else's and the fourth method was never patented. Some of the Japanese firms, once they started getting nailed for royalties, switched to the fourth method because it wasn't covered. Others just went ahead and paid the royalty.

Wolff:

I'm afraid I lost the point. You said someone was responsible for getting the patent approved.

Koch:

Ligget is the one who went back to the patent office with our patent attorney and presented the difference between the RCA (/RCA_(Radio_Corporation_of_America)) patent and ours, which made ours patentable.

Wolff:

Was there a lawsuit or anything like that?

Koch:

No. They simply were not going to allow the patent.

Wolff:

Oh. All right. Now we're talking about the oscillator/mixer? My electronics is rusty.

Koch:

That's right. That's called a converter combination. The converter replaced an oscillator and mixer. Okay? A single transistor (/Transistors) instead of two.

Wolff:

After you designed this, your patent attorney took it to Washington and at first they were not going to give him the patent?

Koch:

That's right. I was not here then. This was probably in about 1957.

Wolff:

All right. You were the only engineer really working on the electronic design.

Koch:

Yes, until right up near the end. Then Bob Ligget, the fellow that did this relative to the patent, began assisting probably in October.

Biasing Circuit

Wolff:

Was the other major thing you developed the biasing circuit?

Koch:

That's right.

Wolff:

What is the story with that?

Koch:

Typically in a transistor (/Transistors) there is a transistor (/Transistors) stage. There is a metal resistor (/Resistor) and there are two resistors (/Resistor) in series between the plus supply and ground, and the base goes to the junction of the two resistors (/Resistor). What we had then was the current drawn by those two resistors (/Resistor) plus whatever current was supplied to the base. What I did was take the voltage that was at the emitter of the output audio stage and, off of it with a single resistor (/Resistor), biased the rest of the bases. By doing this, I saved the network current plus one resistor (/Resistor) per stage. It was not only an economical saving but it gave more battery life. The only way we could get this thing to play back then was with a 22 1/2-volt hearing aid battery. The life of that thing was not very long. Eventually the transistor (/Transistors) radio (/Radio) business went to either 6 or 9 volts.

Wolff:

What battery were you using in this?

Koch:

22 1/2-volt. It was called a hearing aid battery. It was the same size as today's 9-volt transistor (/Transistors) battery.

Wolff:

This self-biasing was a way to get more battery life?

Koch:

Yes. And saved some components.

Wolff:

Okay. That came after the oscillator/mixer development. Right?

Koch:

Chronologically I don't know when I did that.

Gaining Familiarity with Transistors

Wolff:

It is kind of intriguing that you had never even seen a transistor (/Transistors) before. Then suddenly you were designing these innovations and new circuits. Did you start studying up on transistors (/Transistors)?

Koch:

I didn't have time to take a class. I still had a scholarship left at Harvard but I never went back. I've been a radiation/antenna type. I'm glad I didn't. Almost everything I've gotten into, I say that I got it from the school that I call "SHOE": School of Hands-On Experience. At Cornell they told us, "What we are giving you is a foundation. You've got to build on it." They gave me a good foundation in the fundamentals. They told us it was going to be an expanding field, and it was true. They didn't know what was coming.

Wolff:

You just started right to work with these really new components that you'd never used before. You didn't take a transistor (/Transistors) course or anything?

Koch:

No.

Wolff:

You just started working with them.

Koch:

We picked up a book but I didn't have time to read it. I looked at it and picked up some pointers. Also of course the people at TI were experienced, and they probably gave me some pointers on thermal runaway and some other fine points.

Wolff:

What's thermal runaway?

Koch:

It depends upon how the circuit is designed. Transistor currents increase when the temperature goes up. When the currents go up the dissipation goes up, which causes the temperature to go up. The next thing you know, the circuit goes out of commission in one of two ways: (a) it just stops working, or (b) you have a disastrous failure — in other words, the transistor (/Transistors) breaks. Conservative circuit design will prevent this. With the improvement of components over the decades people don't even think about it anymore because they don't have this problem. They are not so inclined to do this, but it can still happen.

Wolff:

Did they come down here much before you got into production while still doing the design? You talked with them about things like thermal runaway.

Koch:

I don't remember any of that in detail.

Wolff:

You did have some help from the TI people.

Koch:

Yes. I had a little bit of time to look through the book, though I didn't read the book. However, I had been working with TV boosters in the high-band channels up to 13 and the tubes that we were using up there. Normally one thinks of a grid as being a very high-impedance input, but when it gets to high frequencies they are not high-impedance input; they are quite low. It turned out the impedances in the transistor (/Transistors) stages that I was dealing with were almost identical to this vacuum tube (/Electron_(or_Vacuum)_Tubes) in 200 megacycles. Interfacing into low-impedance inputs and from relatively low-impedance outputs was nothing new to me. My vacuum tube (/Electron_(or_Vacuum)_Tubes) experience was almost a parallel to what I was running into with transistors (/Transistors).

Wolff:

That's interesting.

Koch:

And then I came up with thumb rules such as "the impedance that the base looks into shall be no greater than three times the value of the resistor (/Resistor) and the emitter," which kept me out of runaway problems. Those are thumb rules.

Wolff:

Where did that thumb rule come from?

Koch:

I don't know. That was with germanium. I had a similar thumb rule of 10 to 1 with silicon. Today I go up to 20 to 1 or even higher.

Wolff:

There was some contact with TI people while you were doing the design, but they were not involved with you very much. Is that correct?

Koch:

Yes. They kept me advised and supplied with their latest samples, because their process was continuously changing.

Meeting the Deadline

Wolff:

When was your deadline for the design?

Koch:

We had to get into production the first of November.

Wolff:

November 1st was the production date.

Koch:

Essentially.

Wolff:

When did you have to have your design finished? The day before? Is it that close?

Koch:

We had to have the mechanical design done for tooling the case. We got the plastic molding tools out of Chicago the last week in October. They came into town at 2 o'clock in the morning.

Wolff:

What came into town the last week in October?

Koch:

The molding dies for the case. The purchasing agent (Floyd Hayhurst) (/Oral-History:Floyd_Hayhurst) drove up to Chicago and late that day loaded them in the trunk of his car and drove them into town straight to the molder, which was a 24-hour operation. Then he called me up. I was here at the plant, because I was expecting him to come in. Already we had had samples of every other component, so I had some built-up chasses. I got in the car and drove down to the molders and they ran off a few cases and, "Oh boy. Is it going to fit?"

Wolff:

You had all fingers crossed, right? That's what you're saying?

Koch:

Yes, and a few other things. It fit, but the case after coming out of the mold was tending to warp. The molder said, "That's no problem." They make wooden fixtures and slap them on when they come out of the mold. As they cool they won't tend to twist.

Wolff:

You were saying the purchasing agent loaded them into the trunk of his car and he came in at 2:00 a.m.?

Koch:

Yes. That was the tools. That was the dies for going in the molding machine.

Wolff:

The dies for the case. And then you had some molds made.

Koch:

They made some cases off the molds and I tried a chassis assembly in it. It went together, so now we had a radio (/Radio). And it fit in a shirt pocket.

Wolff:

This was at the end of October?

Koch:

Yes.

Recap of Events

Wolff:

All right. Now let me go back. The meeting with Haggerty (/Patrick_E._Haggerty) and Webster was in what month?

Koch:

Let me get a calendar. That was a long weekend. That is my recollection, because the Fourth of July was on Sunday. I don't know whether we started the project on Monday or Tuesday. The meeting had to have been the 1st or 2nd of July.

Wolff:

They gave you the project goals at the meeting. They estimated something over $100 for their germanium breadboard, which was too expensive. What did they tell you was the price at which they needed it to sell?

Koch:

My recollection is under $80. It may have been under $70.

Wolff:

You major goal then was to find a way to produce this so that it would sell for under $70 or $80. Right?

Koch:

Right.

Wolff:

And the first job you had to do was cut down the number of transistors (/Transistors).

Koch:

No.

Wolff:

Can we say it was the most important thing? Or was it all a lot of simultaneous things that had to be done?

Koch:

First of all we had the manufacturing techniques. What we had to do was to reduce component costs anyplace we could. My recollection is that we put it on the market at $49.95. TI states otherwise.

Wolff:

You came back from that meeting basically knowing that you had to not only design this but you had to cut the component costs. One of the areas was the transistors (/Transistors) and you worked on that.

Koch:

That was the most expensive thing in there, so I wanted to reduce transistor (/Transistors) count.

Wolff:

That's what I thought. The major thing was to reduce the transistor (/Transistors) count because they were the biggest part of the cost.

Koch:

That's right. However that was not the way they stated it. That was my own concept.

Wolff:

Yes. You did that right away at the meeting by getting rid of one transistor (/Transistors) just by looking at the circuit and replacing the detector transistor (/Transistors) with a diode (/Diode). And later on what saved another transistor (/Transistors)?

Koch:

That was the oscillator/mixer.

Wolff:

Right.

Koch:

It is ironic, but the diode (/Diode) we put in there was a Raytheon.

Wolff:

You mean down at TI?

Koch:

No. The one we used in production.

Wolff:

That's right. He mentions this. You came back from that meeting and realized that you had to do this in four months because you had to be in production in November. Were you nervous about this?

Koch:

No.

Wolff:

Why did you feel you could do it when you'd never seen transistors (/Transistors) before?

Koch:

I don't know.

Problem Solving

Wolff:

All right. You weren't worried. Was there anytime during the summer as you were working along that you began to worry about making the deadline? Did you run into any obstacles?

Koch:

The only time I worried was over whether or not that chassis was going to fit into the case. Even then, I slept that night. I have always found this: When I get into a problem I walk away and leave it, and when I come back it's solved.

Wolff:

Would you give me an example of how that worked here?

Koch:

Okay. I was trying to get components out and was trying to use 455 IF transformers (/Transformers), which was impossible because of gain. I had to do something in the area of the oscillator/mixer. Then it struck me how to do it. That's all.

Wolff:

That was in the car that you had that idea.

Koch:

Yes.

Wolff:

Why did you try to use 455 IF transformers (/Transformers)?

Koch:

The components were available. One couldn't get IF transformers (/Transformers) at 252.

Wolff:

He says here that "special miniature 252 Kc IF transformers (/Transformers) were used."

Koch:

Yes. We designed them here. Vocar, who was in the vibrator business, manufactured them for us. They were glad to get the job. You know what a vibrator is, right?

Wolff:

I'm afraid I don't remember.

Koch:

Okay. That's a device that's in a tube automobile radio (/Radio) as a d.c.-to-d.c. converter to get from 6 volts — as it was back in those days — up to the 200 volts needed for plate supplies. Mallory was a big producer of those. Once transistors (/Transistors) started coming out, low-voltage devices became apparent. Vocar knew they needed to diversify. I have no idea how we got together with them. Ray Morris did the mechanical design on the transformer (/Transformers), because he had worked at Coilcraft.

Wolff:

I got confused because you said knew you had to use 455.

Koch:

I tried to use 455 IF transformers (/Transformers) because they were already on the market.

Wolff:

And that didn't work.

Koch:

It lost gain. I could not get the sensitivity. We were pushing the frequency ceiling on the transistors (/Transistors) as it was, and going up to roughly twice the frequency was pushing it even further.

Wolff:

Did we get onto this because this was another problem you had to overcome? You wanted to use the 455-Kc transformer (/Transformers) because it was available, but found you could not because you lost gain.

Koch:

That's right.

Wolff:

Therefore you knew you had to design another one.

Koch:

Correct. We designed the transformer (/Transformers) here. Ray Morris did the mechanical on it. He knew sources for cup cores and all that kind of thing. I did the electrical design.

Wolff:

It also says low-impedance antenna coils were not available so you wound your own.

Koch:

That's correct.

Wolff:

That is yet another problem.

Koch:

Right. Plus it had to be small enough to fit into that case.

Wolff:

Yes. We just talked about the electronic circuit design, but were you responsible for all these components? Did you supervise the development of new miniaturized components?

Koch:

I had to work with the radio (/Radio) condenser and I was up at Jensen on the speaker. I think we worked through the rep here in town, which was Central Avalon ceramic capacitors. The only things that were standard off the shelf were the resistors (/Resistor). We had never done a circuit board assembly before at this point – as far as I can recall. That was brand new.

Wolff:

Did you do that too?

Koch:

I laid out the board. I think in the final run Bob Ligget was involved in some of that.

Wolff:

Your recollection is that you were always confident that all this would come together by October and that the only scary moment was whether the chassis would fit into the case.

Koch:

Yes. I don't know how many times we went through the stack-up of dimensions inside that thing to be sure. All of this was being tooled at once and there was no room for a mistake. I didn't have time to get scared, Mike. I think if I had gotten scared I would not have been able to do it. You know what I'm saying? Tudor could see no progress. That's when he got itchy. I guess he thought maybe we bit off more than we could chew.

Wolff:

Did he look over your shoulder a lot?

Koch:

No. It just happened to be that he came in that night when my wife was in here with me. She started cleaning up my desk and, "Hey, here's a letter from McNabb that hasn't even been opened. It's dated a year ago." I remember Tudor saying, "Think he's still waiting for an answer?" McNabb was an IRC resistor (/Resistor) rep, and he sent out a monthly calendar or something like that. I knew what it was.

Procuring Components

Wolff:

Okay. You were working full speed on all of this. Did you contact these companies for the components too? Did you initiate that?

Koch:

A lot of these components were run down and handled by our purchasing agent, Floyd Hayhurst (/Oral-History:Floyd_Hayhurst) and his company. It was their job to find these things. I just said, "This is what I need." Floyd is here in town if you want to talk to him.

Wolff:

And his home is in Indianapolis?

Koch:

Yes. He is semi-retired. He is in the rep business.

Wolff:

Floyd Hayhurst was responsible for finding the components to your specs.

Koch:

Yes, he and whoever else worked with him.

Wolff:

What do you think was the hardest problem you faced in this effort?

Koch:

As I look back on it, I suppose when I really should have gotten shook up was when I found out the breadboard that Roger did had was made by Cornell Dubilier, one of the big capacitor manufacturers. I'm pretty sure it was Cornell Dubilier. The breadboard had electrolytics in it, so I called up the company and said, "I need some samples. Would you send purchasing a quote?" and whatever. They said, "Oh, we're not going to make those in production yet. These are just an engineering operation." Oh boy. They were only about an inch long and a quarter inch in diameter.

Wolff:

What did you do?

Koch:

I got hold of purchasing and they ran down a source in Nashville. We got into trouble with our first source. Their components dried out and went dead. Then we found a second source in Nashville. They put theirs in a ceramic tube, which was not subject to drying out, so that got us out of trouble. However, we could have been in really bad trouble there for a while. There was nothing else that could be put in there except those miniature electrolytics. We were probably the first high-volume manufacturer that ever used them.

About the radio (/Radio) condenser. The way they make a variable capacitor for radio (/Radio) tuning is on a U-shaped frame. The shaft goes through one end and at the back end they put in a seat, and there is a single ball. That frame, when they made it, was over-formed. In other words, the opens are toward each other. Then when they throw it together that thing is sprung. That is the tension that holds that thing together. A lot of that spring is in that bottom leg of the U where it gets bowed a little bit. When it came to this narrow capacitor with a very short frame, they didn't know whether they could control that spring tension that's in the frame to hold the thing together properly. It could be too tight or too loose or something. Therefore they put in a setscrew to hold that single ball thrust and adjusted the setscrew to get the proper thrust on it. Because of that, when we did the case we put a depression in the back of the case where that setscrew was in order to clear it. That's how tight we made the thing.

Wolff:

That's interesting.

Koch:

Eventually they could control it and took the setscrew out and we ground that part of the die out so there would not be that depression in the back.

Wolff:

Did the first models have the depression?

Koch:

Yes.

Production and Failure Rates

Wolff:

Let's talk about the next stage now, going into production.

Koch:

Audio File
MP3 Audio
(460_-_koch_-_clip_1.mp3)

Once we had a publicity release on this, which was the latter part of October, we let the factory know that we were going to make transistorized (/Transistors) radios (/Radio). I started a rumor going around that "there is no such thing as a bad transistor (/Transistors)." These troubleshooters were used to replacing tubes when a radio (/Radio) didn't work. If that didn't work they started looking for other problems. Well, these transistors (/Transistors) were soldered into the circuit board and if they started changing transistors (/Transistors) like they were used to changing tubes they were going to damage transistors (/Transistors) from excessive heat handling and the circuit boards would also be damaged. Therefore I started the rumor "no such thing as a bad transistor (/Transistors)." We were in production for maybe a couple of weeks when a tester came upstairs and said, "I think I found a bad transistor (/Transistors)." I checked it out. Yes, it was a bad transistor (/Transistors). I told him, "There will be bad transistors (/Transistors), but let's make sure that what we are taking out is bad before we screw up the circuit board." The rumor served its purpose. Just a little sidelight. **Wolff:** That's interesting. I understand that you had failure rates as high as 50%? **Koch:** At the very beginning, yes. If it wasn't one thing it was another. **Wolff:** What did you do when you started getting these high failure rates? Was that a crisis? Were people upset? **Koch:** TI was upset. They sent a guy up here from their marketing department. He lived up here for a while. **Wolff:** Was that Harris? **Koch:** That was Harris. They were upset that we weren't getting more stuff out the back door. I went down to my office, and just pulling numbers out of a hat calculated a probable board failure rate coming off the line. It came out to something like 12%. Our experience later on was about a 15% rate. **Wolff:** In other words, you felt that things could be corrected to bring this down to 12%? You felt that there was no inherent reason why they should so unreliable? **Koch:** It was a little bit of everything. We had so many new components in that, and we had the vendors' problems plus our own. It took a little while, but things settled down. **Wolff:** Would you elaborate on how you got down from 50% to 12%? **Koch:** We just kept at it. **Wolff:** He says here in his paper you that needed new test fixtures and spring-loaded phonograph needles were used for test stations. **Koch:** That was an innovation we did. The process was that once the board came off the solder pod it went into one of these test fixtures that put signals into it. There were some meters sitting there, and we either got the right results out of it or it went to troubleshoot. After that it was assembled onto the chassis. It was married with the volume control, the capacitor, the antenna and put into a case and then went through a final test as a complete radio (/Radio). We used a lot of new innovations to build that thing. It was necessary. And we had people that thought nothing about it. If they saw something wasn't working right, or could be done better, they made something new to do it.

Dip-Soldered Board & Factory Innovations

Wolff:

What do you recall as the most significant innovation?

Koch:

Our dip soldering for one thing. RCA (/RCA_(Radio_Corporation_of_America)) said it could not be done. The pattern on our particular board design was too close together and therefore they thought we could not dip-solder it. We didn't know that, so we did it.

Wolff:

Did you show it to RCA (/RCA_(Radio_Corporation_of_America))?

Koch:

Everybody in the industry got hold of our radio (/Radio).

Wolff:

How did you know what RCA (/RCA_(Radio_Corporation_of_America)) thought?

Koch:

They told somebody, "That board cannot be dip-soldered. It has to be hand-soldered."

Wolff:

That's interesting. You went ahead and dip-soldered it anyway. How did you accomplish that?

Koch:

The factory came up with what I call a Ferris wheel. A Ferris wheel has got these gondolas. It had six arms on it. Three of those had a paddle, and when it came down across the solder pot — which was probably about a foot long and maybe six inches wide — these paddles would go across the top of the pot and then come down and wipe the dross off of it. Dross is being collected down at one end that way, dross being the oxidation of solder. There were three of those, and the ones in between had cradles in them into which a girl would take one board out and put in a new one. That would go across the pot, and that soldered it.

That was a factory innovation. Then we had these component leads that stuck out of the bottom of the board. They had to be cut down close in order for the thing to fit properly in assembly. We had very little room with which to play. They built a thing that had some milling cutters, end-type cutters. The board would go into this thing and those things spinning around cut all the leads off.

Wolff:

That's very interesting.

Koch:

There was nothing like this on the market. These were not common techniques in high production. The thing that built this company was the innovations in the factory to produce, if you want to get right down to it, with producible designs. When you get into a project like this, Mike, you never think of the fact that it's not going to work. You don't even think about it. It's a degree of self-confidence, I guess.

Wolff:

You had a skilled factory crew that was able to innovate whatever needed to be done.

Koch:

To produce this thing economically. Bit by bit the failure rate came down and for a while they were running down by a calculated 12% and then it went back up to about 15%. It looked like the typical should have been about 15%. I did that to convince Buddy Harris that was the kind of rate we were eventually going to wind up with once we got those problems solved.

Wolff:

What were some the problems that were causing the high failure rate?

Koch:

I don't think there was any one thing in particular. It was just this, that and another thing. We had a lot of radios (/Radio) that troubleshooters could not even figure out what was wrong with them. We just disassembled those, salvaged the more expensive parts and chucked the rest.

Wolff:

That's very interesting.

Koch:

Throughout the entire production run, transistors (/Transistors) kept improving. Their internal capacities went down and their gains went up. I had to change oscillator coils every once in awhile because the transistors (/Transistors) had too much gain for the coil that we were using. The circuit got into trouble with the nano and nono skweging.

Wolff:

What is that?

Koch:

It goes into oscillation and then quits.

Wolff:

How do you spell skweging?

Koch:

I don't know. I don't know whether it's even in the dictionary. Anyway, it was normal. As gains improved we got into some of these other troubles, so we redesigned the circuit.

Wolff:

The first radio (/Radio) came out in time for December. He says a year later you changed the tuning knob design and went to pnp transistors (/Transistors). The ones you used in the first radios (/Radio) were npn transistors (/Transistors).

Koch:

Npn grown-junctions. I don't remember what was different in the pnp construction. I think that conversion was done by Bob Ligget.

Wolff:

Okay. It says battery power was still at 22 1/2 volts, and then you went to a new model where you got— [end of recording of tape 1 of 1]

[End of Tape 1. Second part of interview on tape #468]

TR6 Transistor and Mark Shepherd

Wolff:

In late 1955 the model TR6 transistor set was introduced, and you had designed it.

Koch:

That's correct.

Wolff:

It came in a leather case with a leather handle. Smith said that you and Bob Cox designed this in one afternoon. Tell me about that.

Koch:

The sales department came up with the concept of what they wanted with this particular radio. I was chief engineer then and Bob Cox was in purchasing. I said, "Let's get together and we'll figure out what we are going to put in this thing." Then I wrote a schematic based upon his knowledge of available and inexpensive components.

Wolff:

What was the assignment that you were given?

Koch:

The concept was a leather-cased radio with the volume control on one end and tuning on the other and a perforated front for the speaker and we put a 4" or 5" speaker in it. We used a specialized battery pack that was primarily the equivalent of six C cells, making a cardboard battery (/Batteries) pack adapter that would go in place of the custom 9-volt battery so one could buy C cells at the corner drugstore. We put in six of those, and that was the power supply. We had designed enough radios by then that what we had to do was obvious, looking for the least expensive component arrangement. We may have started at 5 o'clock, and it took us only about an hour to come up with the schematic.

Wolff:

What was the main difference between this and the first model, the TR1? What did they want that you didn't have in the first model?

Koch:

This was a home or portable radio. It had a bigger speaker and more audio power like a modern tabletop radio.

Wolff:

All right. This was 7" x 5" x 3", so the assignment was to build a good portable radio rather than a shirt pocket radio.

Koch:

That's right.

Wolff:

I see.

Koch:

The shirt pocket was limited on audio output and sensitivity. Of course improvements in transistors caused sensitivities to improve. When we first started, Texas Instruments had criteria as to what they thought would sell from a sensitivity standpoint. In other words they had a radio in which they could decrease the sensitivity to the point where they didn't think it was satisfactory any longer. Compared to a good table model vacuum tube radio I would have to say that the sensitivity was lousy. A manufacturer had a bunch of "American Fives" as they were called – a typical configuration of a 5-tube table model – on the market and we designed a new one for them. When we got hold of one of those they had on the market we discovered that their sensitivity was lousier than our TR1, so I didn't feel too bad. Compared to what could be done in vacuum tubes it was lousy, but it was adequate. TI determined that threshold.

Wolff:

Did the TR6 also have germanium?

Koch:

Yes.

Wolff:

When did you go to silicon?

Koch:

I don't think we ever built a silicon AM broadcast radio. Our first major use of silicon was for a telemetry receiver we did for the Navy I think.

Wolff:

Do you remember meeting Mark Shepherd?

Koch:

Oh yes.

Wolff:

How was he involved?

Koch:

Mark Shepherd was the head of the Transistor Manufacturing Division at Texas Instruments. We got into trouble one day because of transistors that were failing, and Mark came up here with one or two of his engineers. He thought we were breaking them in the solder line; in other words he thought they couldn't take that much heat for that long.

Wolff:

Do you mean with your Ferris wheel?

Koch:

Yes. The cans on those transistors are called crystal cans. Do you know what a typical miniature quartz crystal can look like? It was that same can.

Wolff:

Give me the dimensions for the record.

Koch:

Roughly 1/2" wide and between 1/8" and 3/16" thick I guess. I have the actual dimensions over here somewhere. They had three leads on them: one base, [unintelligible] and collector. The can is soldered onto the base. I took a can off and stuck a thermocouple on one of the transistor supports inside of it. That was in a radio assembly – a board assembly. We took it down, put it on the Ferris wheel and ran it through the solder pot. I chased the temperature with the thermocouple bridge. Mark took one look at the reading and said, "We've got problems. Let's go back home." In other words, we weren't doing it in the solder pot. They had a production problem. Little things like that caused our failure rate to be high. If it wasn't one thing it was something else. From the rates we were getting I predicted that out of a hundred radios that went through troubleshooting, one of them would go around that loop five times. In other words some of them would go through troubleshoot twice. This is because you only find one trouble at a time typically. It was that predictable. I'm not a statistician, but I had one radio that went through that troubleshoot five times.

Starting at Martin, Family Business

Wolff:

Is there anything else that you think should be mentioned? Any questions I have not asked you or anything that comes to mind that is particularly worth noting about the development of the transistorized portable radio?

Koch:

It was the forerunner of a lot of things to come I guess. We were a lot slower getting into the transistorized monitors than we should have been.

Wolff:

TV (/Television) monitors?

Koch:

No, police band monitors.

Wolff:

All right. That was a later product.

Koch:

That's right.

Wolff:

After the TR6 radio got into production did you basically leave the transistorized radios and go on to other things?

Koch:

That's when I left. I went back home to Denver in late '56.

Wolff:

You quit Regency in 1956?

Koch:

Yes. I had started making banana plugs back in the late '40s. My dad and mother continued to assemble stuff at night. He would get them packed and take them to work to mail them. In 1956 my father was a vice president of [unintelligible] in charge of electrical operations. My mother called me and said, "This is too much for your father with everything else he's got to do," so I went to Tudor and said, "I'm going to have to leave." They gave me a great sendoff. Then I went and interviewed at Martin. They were starting to build a factory out there and the project on the Titan missile had already been underway for about three months. I got a job with them.

Wolff:

The idea was that you could run the family business at night?

Koch:

Yes. I took it away from my dad and put it in our basement. Eventually we moved into a building.

Wolff:

You were making banana plugs?

Koch:

Yes.

Wolff:

I guess I was thinking of something else. What are they?

Koch:

It's easier to show you.

Wolff:

How would you describe them? For what are they used?

Koch:

They're a determination [?] for test leads for one thing. We had a lot of adapters and other stuff too. It was a line of general hardware for use in laboratories and hobby shops or hobby basements. We sold to universities.

Wolff:

Is banana plug a standard term?

Koch:

Yes. It's been around longer than I.

Wolff:

Okay.

Koch:

It put us in the plastic molding business. I had done some mold design, and it was that background that assisted me in designing that plastic case for the radio. When the molder came in he reviewed our design to see what it was and how much it would cost us. He went through our prints and had a suggestion on the snap-fit enclosure. It was a little snap-on lid where you had to squeeze the thing to pull the cover off to change the battery. He had a suggestion that was an improvement over what I had done, but it made the tools a little more complex. He made the remark, "This is the first time I have gone into a place like this with an electrical or mechanical producer and had a moldable design." I had been through it all since we did our own molding. If you've got shrinkage and serious section changes the result is an indentation in the outside surface – which is a blemish or a snake [?] as they call it. If things are designed properly those things can be avoided. Most electrical engineers have no concept of that. A lot of mechanical engineers don't either, unless they specialize in plastics.

Wolff:

That's very interesting. You left and were working in the family business. When did you return to Regency?

Koch:

My wife ran the family business while I still worked at Martin, and we got some employees. At Martin I had a project designing a 400-megacycle solid-state receiver to replace a vacuum tube receiver that was used in the missiles, so we had an airborne environment. That was pushing the state of the art in '57, and we did it. In January of 1960 I left Martin and went into my own business full time and did local custom design. We manufactured circuit boards and did custom assembly around the Denver area – basically as a consultant.

Working at Regency Again

One of my clients, a sales manager, came in and said, "I've got $50,000 to invest in the design of a solid-state police band monitor." I felt I owed something to Regency – and it was still Regency then – so I called Ed Tudor and said, "We were talking about designing a solid-state monitor. You are either going to do it or you're not. If you're not, I've got somebody else who wants to do it." He said, "Get on an airplane and come out here." They were bidding on a 200-megacycle telemetry receiver for NAFI – Navy Avionics Facility in Indianapolis. They had a bid out for production of 140 units of these receivers. It was a tube set, and we were bidding on it. It had already been manufactured two or three times. It had to have an improvement put in it though. However, they wanted a solid-state receiver, for which they asked Washington for development funding. Washington refused. We bid at a solid-state equivalent of the [unintelligible] package that we got. It had to go in the case and had to interface with the same power supply – antennas and everything – and we bid at solid state. It was underbid, by the way. I got them to double their price, and we were still the lowest bidder.

Wolff:

We being Regency?

Koch:

Yes, Regency. I came out here and helped them prepare the bid set. Hazeltine, who were here in town then, bid on it solid state. The original manufacturer of this tube set back in Philadelphia bid on it. We were low and Hazeltine was the highest. I knew where Teledynamics would come in on the bids because they supplied stuff to Martin when I was there. All bids that were non-responsive got thrown out. We took an exception to the power supply since we wanted to use a different voltage coming into it. Then we redid our bid. I have forgotten what happened on the others, but we took an exception to the delivery date. They wanted delivery on the first week of January, and this was already going on into late November.

Wolff:

You were saying you went to work at Martin and then you came back and Regency was bidding on the 200-meg solid-state receivers for the Navy.

Koch:

We resubmitted our bid, we raised the price to what we knew would get it and revised our delivery date to meet their demands. That was about the first week in January. I think it was January 6th. We got the contract. We started that development the Monday after Thanksgiving. It was all silicon as I remember.

Wolff:

You then remained at Regency?

Koch:

I remained a consultant up through September of '62. Then I went back on the payroll as a vice president in charge of engineering. I was still commuting between Indianapolis and Denver.

Wolff:

Were you still running the banana plug business?

Koch:

Yes. I did some product development in my own facility to bring back here. I don't remember what year I resigned my position. Then I went back on the bench as a product design engineer at Regency, involved in CB transceivers.

Wolff:

I see. You didn't like being a vice president?

Koch:

If you aren't here all the time it's hard to do. I went back on the bench.

Wolff:

Were you still running the family business out in Colorado?

Koch:

Yes, my wife was running it. I did the CB designs in my lab out there. I had full malt [?] shop facilities for doing chassis work and all that. As soon as I got the job designed I brought it back here and we ran it through drafting and into production.

Wolff:

It was a Regency product?

Koch:

Yes.

Retirement and Consulting Work

Wolff:

Did you work at Regency up until this past summer when you retired?

Koch:

That is correct.

Wolff:

And now you are here as a consultant. What kinds of projects generally do you work on now? Do they have one main product here?

Koch:

What I have been involved in here is a design, a test fixture, for incoming inspection for testing transformers (/Transformers). I have also been involved in dealing with certain problems down in the factory. We have a production engineering department that traces those down and I do a lot of work for them.

Raytheon Diode and TR1 Schematic

Wolff:

You were saying earlier that this was one of the best-kept industrial secrets. You also talked about calling the person at Raytheon for information about the diode (/Diode). Would you tell that story again?

Koch:

The diode that we put in to replace the detector transistor was a CK-706 I believe. It was made by Raytheon. I called them up for details, pricing, etc. and left them with the impression it was going into an FM table model radio as a discriminator detector for FM. They were developing a radio then, I would assume, since they came out in February. They had no idea what we were doing and we didn't know what they were doing.

Wolff:

We're looking at the schematic now of the TR1.

Koch:

This is the converter. [Unintelligible] the audio. That's where the diode is that replaced the transistor that was the detector. This is the converter patent circuit. Typically this would have been biased this way if I redraw that down here. It was a transistor base. The resistor to the supply went down to here, and from there down to the [unintelligible] supply. [Unintelligible] This doesn't look right. This has got the [unintelligible] biasing circuit on it which goes from here to here and the base is tied into here. So it gets its bias voltages from this [unintelligible] between ground and up close. The voltage that is at the emitter was used as a source for the bias for here.

Wolff:

For transistor what? I can't read that.

Koch:

That is transistor 3 I guess.

Wolff:

The voltage at the emitter of transistor 4.

Koch:

That's got normal type biasing on it. I thought I had also supplied this one that way.

Wolff:

What is this that we are looking at then? It says the original schematic.

Koch:

Yes, but I'm not sure it is the actual original.

Wolff:

Oh dear.

Koch:

I've got one in my desk. We'll look at it later. This has been redrawn from the original. That is the bias circuit right there. I thought I had a resistor in here.

Wolff:

This is your other circuit, right?

Koch:

That was where we put the diode in to replace the transistor as a detector. I don't remember how it was wired.

Wolff:

And the converter is the mixer oscillator.

Koch:

Yes. This is the oscillator coil and this is the antenna circuit.

Wolff:

Good.

Koch:

The one I have is the original schematic.

Finances and TV Booster

Wolff:

You mentioned before that both you and TI agree that the radio could have been sold for more. You just disagree on how much more. Right?

Koch:

That's right. I remember our original pricing goal as being under $80. I think in Haggerty's talk he said less than that. I think we entered the market either at $59.95 or $49.95.

Wolff:

What did you say about Regency needing the money at the time?

Koch:

Our booster market was disappearing, which was our big income – the DB-410 TV booster. Originally it was two boosters in a single case with a common driveshaft for tuning. One of them tuned the low band channels 2 through 6 and the other one tuned channels 7 through 13. One could switch from high band to low band. They had a common control knob. When I first came out here in '50 that was what I came out here to do, was to get that into production. I came here around the 1st of February and it went into production around May. I had dinner with George and said, "Why don't you just do that with one tube?" He said, "It can't be done because of the extra wiring, the capacity between the wires and whatnot." I let it go at that and got the DB-400 into production. One day I was doing a deluxe booster that had two stages in it and a Mallory induct tuner and I was up against a brick wall. When I get up against a brick wall I go do something else, so I wandered out in the factory. I ran into a line foreman that had a PD degree. That was his thing. There was a tube shortage so we had all our customers on allocation. If they would supply tubes we would supply that many more boosters. In other words, for ten tubes they would get five more boosters, but it took two.

We were getting customers' tubes in and they marked them to make sure they got their own tubes back. This was a mess, as you can imagine, because the testers are the ones that had to put them in and make sure they were tubes that belonged to the customers. Pat said, "We'd get out of all this if we had only one tube in there." I had an idea, so I wandered back into the screen [?] room where I was working and grabbed a booster chassis. With a soldering iron, some wires and whatnot I rebuilt a coil. I made a pair of wires that just hung out there. This was a low-band booster. I soldered those two wires together to become a high-band booster. It worked. All I had to do now was to make the proper switch with the proper coil and we'd only need to put one tube in it. George was in Chicago, so I went in and saw Ed Tudor and Dick Mitchell, who was the sales manager, and told them what I thought I could do. Twice as many boosters and we get rid of this allocation problem and the customer's tubes, so I went after it. I said, "Now we've got a problem. What do we do about George? This is really off the record." We decided, "Okay, here's what we'll do. George will be back tomorrow so I'll put this thing away tonight and I'll get the deluxe out and can be working on that when he comes around to the screen room I'll say, 'Hey, George. I've got an idea' and I'll briefly explain what I think I can do. Then George will come in to the head office and say, "We've got an idea." And they will say, "Well, yeah, it sounds like we ought to look into it." That was their line. George's next lines were to come into the screen room and tell me to get on it. He read his lines perfectly.

Wolff:

This was all before the transistorized radio.

Koch:

Yes. That was 1951 I think.

Wolff:

You're saying the booster market was disappearing and so the company needed a new product.

Koch:

That's right. And hi-fi was not doing as well as they had hoped. I think Ed Tudor said we were using the wrong marketing approach. We went through electronic parts stores. He said we really belonged in [unintelligible] places.

Wolff:

The upshot of it is that they also went along with the too-low price for the radio?

Koch:

Yes. I don't know who established the price. All I know is that our pricing indicated it could be sold for $49.95 at a minimum.

Wolff:

Right. How much did you end up paying TI for the transistors?

Koch:

Ten bucks.

Wolff:

You could have charged more and in turn the radio would have cost more?

Koch:

If we charged more it would have meant that we got a bigger profit.

Wolff:

Right.

Koch:

Which we needed, or could of have used. I'll put it that way.