Worst-Case-Analysis
or
"It Doesn't Work!"

BY JOE KASSER,* G3ZCZ/W3

THE Super Dooper Exciter didn't work. It had been taking up most of Fred's time for the last two months. He had seen it described in his favorite ham magazine. In fact, it had leapt out at him when he had first glanced through the magazine. It was just what he needed for his station. The article had been written with care; construction would not be too difficult and, most important of all, most of the parts were already in his junkbox.

Over and over again Fred read the magazine until he knew the article by heart. He was sure that he understood the reason for every component drawn on the schematic. As for the operation of the unit, he could recite that backwards, upside down or sideways as required.

As the days passed he frantically dismantled his junkbox in a search for the required parts, carefully sorting and testing them. The few parts that he did not have he scrounged from his friends or purchased.

It was early on a Saturady morning when Fred began to build the Super Dooper Exciter by drilling the first hole in a brand new chassis. His work was only interrupted by short breaks to replenish the inner Fred. His understanding XYL aided and assisted him, basking in his happy and contented mood. By late Saturday night the heavy work had been finished. Further work on Sunday was interrupted by his taking the dog for a walk, visiting his in-laws, taking the children to a ball game and some maintenance work on the local two-meter repeater.

After spending most of his free time during the next week on the project, he finished it. The Super Dooper Exciter was ready. Fred cleaned his desktop, all the bits of wire, blobs of solder and spare resistors were reconsigned to the junkbox. Fred plugged the line cord into a handy wall outlet and reached over to flip the power switch.

As he touched the switch he remembered what had happened to his friend Mike a few months before. He withdrew his hand as if the switch had been red hot and yanked out the line cord. He had been visiting Mike's shack just as Mike had completed work on a linear amplifier designed to cut through pileups. Mike had soldered the last connection, plugged in the line cord and switched on the power all in one smooth movement. It had taken five minutes for the black specs of carbon floating in the air to settle down, covering all exposed surfaces with a black layer one eighth of an inch thick. Mike still had a nervous twitch in his right arm and a strange fixation about line cords. He now went around making strange unintelligible noises, and pulling line cords out of wall sockets.

"Not me," thought Fred and settled down to check his work. It took him all day but was worth it, for he did find and correct one small wiring error.

Only then did Fred apply power to his handiwork. The pilot light came on and glared at him. After a few moments it was apparent that the smoke test was proceeding in a satisfactory manner, so while he waited for the rig to warm up, he went to the kitchen for a drink, spoke to the XYL to show that he was still living, settled an argument between his youngest harmonic and the TV set and finally just as he got back to the shack, tripped over the dog. Having got back into the shack he found that the Super Dooper Exciter had completely passed the smoke test.

As Fred examined his handiwork he found that not only could he not tune it up on any band, but the transmit relay persisted in remaining in the transmit position no matter what he did. As he checked and rechecked his work against the schematic without finding any errors his frustration increased. After about two hours, Fred was thoroughly fed up and almost reduced to tears.

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"It doesn't work!" he announced as he kissed his XYL and went to sleep. "It doesn't work!"

The following evening Fred went along to his local radio club. There he met his friend Dave who was an electronic engineer. Over a cup of coffee Fred explained his problem to Dave.

"I can't understand it Dave," he said. "I mean, I checked my wiring against the schematic. I checked the parts against the component list and I can't find any mistakes, yet that relay is switched on."

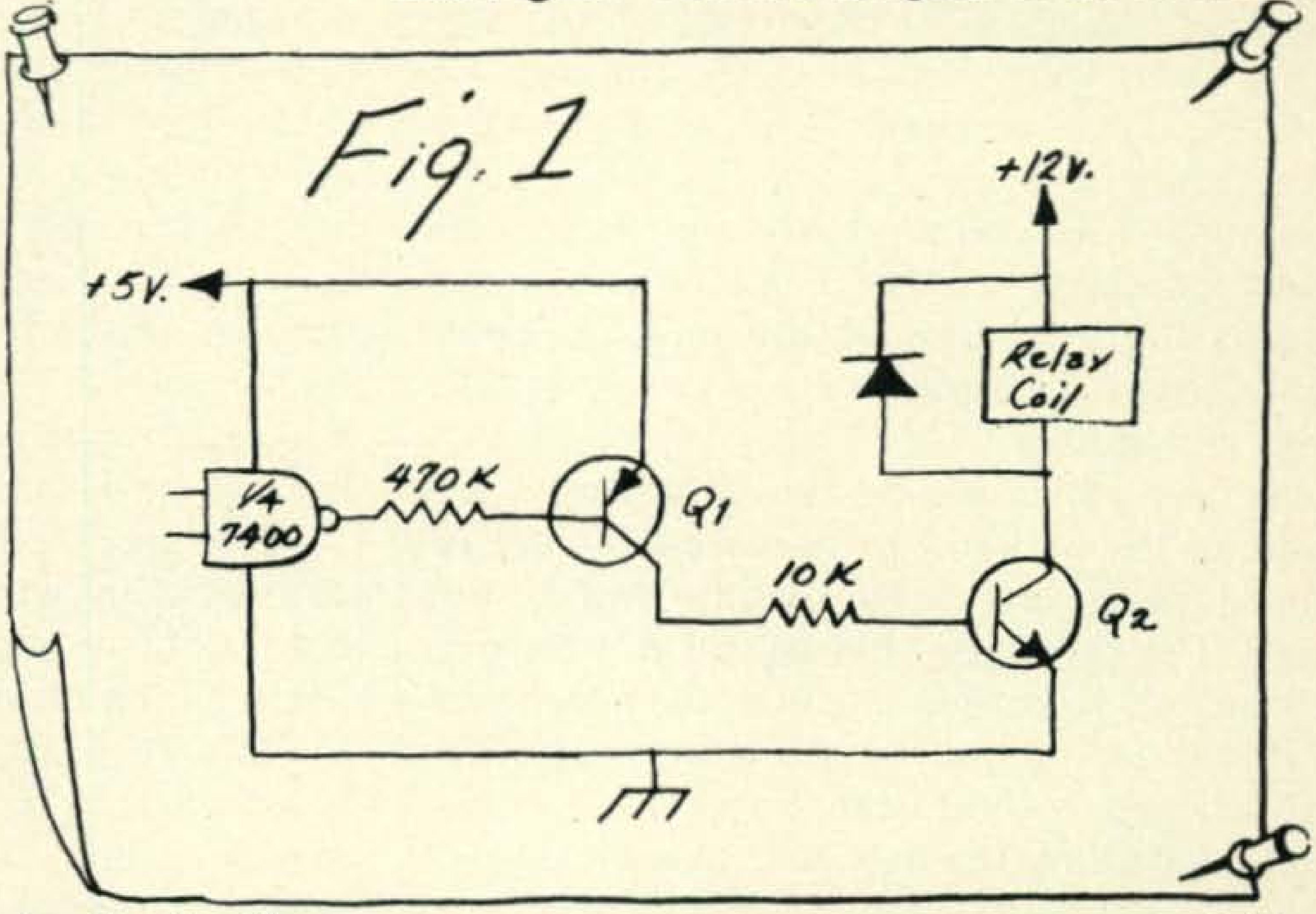
"What parts did you use?" asked Dave "New or used?"

"A mixture, but mostly used," answered Fred, then adding, "I even checked the resistance values on a VOM, so I know that the parts are as marked. I don't understand it."

"Sketch the relay driver circuit on this napkin," suggested Dave "and let's see if there's a circuit error."

Fred sketched the schematic on the napkin (see fig. 1), and they both looked at it. Dave studied it with interest and then asked "What transistors did you use, Fred?"

"Oh, some I picked up last year," was the reply. "The article said that the actual type wasn't critical as long as they were PNP or NPN as required."



"Do you know what kind of gain they have?" queried Dave.

"At least a hundred," said Fred. "I chose the best ones I had."

"That might be your problem!"

"What! How?"

"Well, Fred, most people when they build a rig do not perform any analyses to determine how much of an operating margin they have. They don't check to see the effects of using transistors with lower or higher gains. They usually build it, troubleshoot and debug it. They then operate it for a while and write it up and get it published in a magazine."

"It works, so what?" asked Fred.

"Well, take your circuit for example," said Dave "Do you understand how it works?"

"Sure," said Fred, "listen: the output of the 7400 gate is normally high. Transistor Q_1 is a PNP type and is thus biassed off. When it is off, then the base of Q_2 does not have any current flowing into it. Q_2 is thus switched off and the relay coil is de-energized. When the output of the gate goes low, Q_1 conducts so that Q_2 also conducts and the relay coil is energized."

"Right," said Dave, "But what about the input current to Q_1?"

"What about it?" asked Fred. "I mean the voltage at the output of the gate is either high or low, Q_1 conducts or is switched off. This circuit is independent of the current flowing through the input of Q_1."

"Not quite. Let me show you."

Dave sketched some numbers on the schematic and passed it to Fred (fig. 2).

"Now let's just analyze the circuit," he said and began. "The current gain of the transistor is roughly equal to the output current divided by the input current."

"Of course," interupted Fred. "Even a Novice knows that!"

"OK. Thus, the input current of Q_2 is equal to the relay current divided by the current gain (B_2) of the transistor, and, similarly the input current to Q_1 is equal to its collector current divided by its current gain (B_1)."

"Yes, and the input current of Q_2 is the same as the output current of Q_1," added Fred.

"Exactly, so writing it down we get

$$I_{B2} = \frac{I_R}{B_2} \text{ and } I_{B1} = \frac{I_{B2}}{B_1} = \frac{I_R}{B_2} \times \frac{1}{B_1}$$

$$\text{that is } I_{B1} = \frac{I_R}{B_1 \times B_2}$$

"What current does the relay need to operate?" asked Dave.

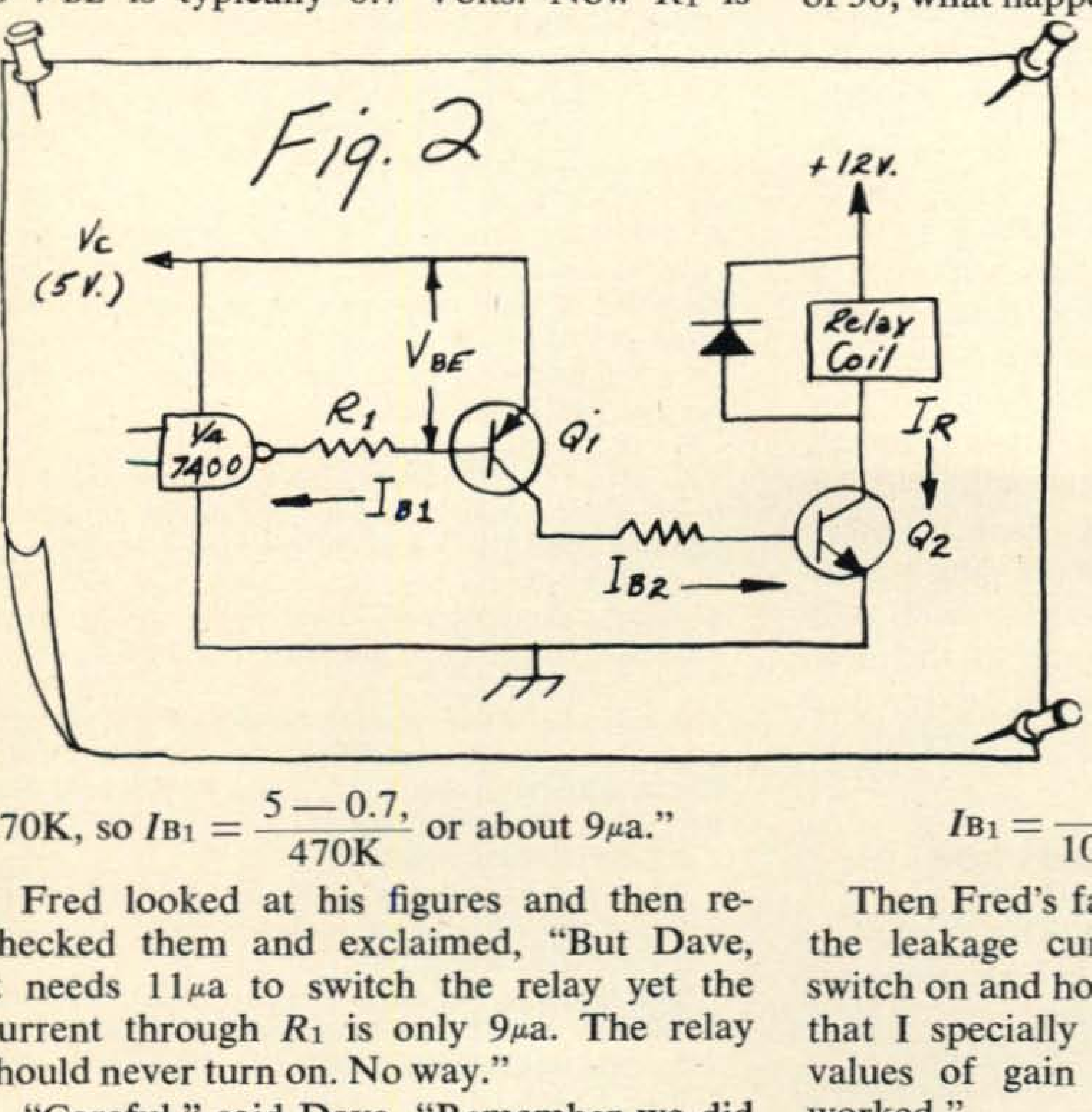
"Oh, about 10ma," replied Fred.

"Suppose," postulated Dave, "that the author had used transistors with gains of 30, what value of input current would be required?"

"That's simple," said Fred, "substituting into the equation, it's

"So when the output of the gate goes low, 11μa of current must flow through R_1 to switch the relay," said Dave. "Does it?"

"I suppose so," answered Fred, "let's check. In the circuit formed by R_1 and the base-emitter of Q_1, the current flowing is equal to the voltage divided by the resistance, that is $I_{B1} = \frac{V_C - V_{BE}}{R}$, ignoring any voltage drop inside the gate. Its a silicon transistor so V_{BE} is typically 0.7 Volts. Now R_1 is



470K, so $I_{B1} = \frac{5 - 0.7}{470K}$, or about 9$\mu$a."

Fred looked at his figures and then rechecked them and exclaimed, "But Dave, it needs 11μa to switch the relay yet the current through R_1 is only 9μa. The relay should never turn on. No way."

"Careful," said Dave. "Remember we did choose a low value of gain."

"That's right!" said Fred "I suppose that the actual transistors that the author used in his circuit must have had higher values of gain than 30."

"Good," said Dave, "now we're getting somewhere."

"But that doesn't solve my problem," said Fred "I can't get that relay to switch off!"

"We're coming to that," continued Dave. "Let's assume that the gate is not a perfect switch and has some leakage."

"But silicon transistors have negligible leakage currents," returned Fred.

"Not necessarily," answered Dave. "A 7400 is a logic device. The manufacturer only specifies a high as being a voltage of between +2.4v. and +5.5v. and a low as being a voltage between 0v. and +0.3v."

"What has that got to do with current?" asked Fred.

"The manufacturer again says that the output transistor of the gate must be able to sink 16ma in the low state, and supply about 10ma in the high state. They don't say anything about leakage currents."

Fred was not yet convinced. "Well, let's allow a slight amount, say 1μa."

"OK. If the transistors have current gains of 30, what happens in our circuit?"

"Well," said Fred, "the leakage current must flow in R_1."

"Right."

"Since the input current of Q_1 must be about 11μa to switch the relay, a leakage current of 1μa has no effect."

"Good," said Dave, "but if those same transistors had current gains of about 100, what value of input current would Q_1 require to switch the relay on?"

"Well" said Fred taking pencil to paper,

$$I_{B1} = \frac{10}{100 \times 100} \text{ ma or } 1\mu\text{a."}$$

Then Fred's face lit up. "Why, that means the leakage current will make the relay switch on and hold it on all the time. To think that I specially chose transistors with high values of gain to ensure that the circuit worked."

"It does work," said Dave, "exactly as you designed it. You only considered the conditions under which you wanted the relay to operate, you did not check for 'not' operating conditions. Think it over, and redesign the circuit so that the relay is not held in by leakage currents yet pulls in when the output of the gate goes low."

"Yes, that's simple enough," said Fred.

[*Continued on page 73*]

Letters *[from page 8]*

pioneering work. I think the world's DX record (reception only) is held by W8JK, who has made fundamental discoveries in antenna design. One of the radio sources picked up by Dr. John Kraus's Ohio State radio telescope has a redshift (change in wavelength divided by the normal wavelength) of 3.5, which, if taken at face value (you probably can't, but that's a long story in itself) corresponds to a distance of 68,000 million light years!

Modern DXing, which is becoming more and more phone rather than code, is forcing a universal language on us—namely, English. I have talked with hundreds of Japanese hams on the air and I continually marvel at their courage and ability in *communication* in a language so different from their own.

The challenges of today's DXing are greater than ever. The 30 db gain antenna for 10-15-20 meters is still to be built. EME is only in its primitive beginnings as are television, teletype and satellite communications. DXing is far more than just a Numbers Game.

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It Doesn't Work *[from page 31]*

"It's just a question of using the same equations but putting in differing . . . I mean different . . . values of current gain for each condition. Why didn't I think of that?"

Fred was so excited that he spilt his coffee over the napkin. That broke the spell. It was then that both Fred and Dave looked up to find that to their surprise, all the club members were standing around them and had been following their conversation.

"Say Dave," said Mark, who was also the club president, "what you say is very true. Most of us find that our unit works, do one or two calculations and assume that because our unit works, so will any others. Why I can remember an article years ago in which the author had built a piece of RTTY equipment full of gassy triodes and other such stuff. Lots of people tried to duplicate his design and couldn't get it to work. He had to publish another article a few months later to explain."

"I remember that," said Dave, "but don't blame the magazine. They can't worse-case-analyze all the designs that they publish."

"Worse case what?"

"Worse case analysis," replied Dave. "That's the fancy name for these calculations."

With that the meeting came to a close, the coffee cups were collected up, the ashtrays emptied and the members dispersed into the parking lot.

Fred drove home happily that night, he didn't even turn on his two meter f.m. unit. He was too involved in thinking over his conversation with Dave. His XYL was pleased to see him cheerful again. When she inquired as to the reason, he replied "always do a worst case analysis on both the operating and the non-operating conditions of any circuit."

Of course she didn't understand a single word. ■

Antennas *[from page 46]*

idea of a metal mast getting tangled up with the antenna. So my beam is mounted on a vertical, wood mast about three feet high which is supported by the rotator. That way, there's no vertical metal structures in the immediate field of the antenna."

Pendergast carefully tore the page out of my log book and put the sketch in his pocket. "Thank you, thank you, thank you," he said. "Do you have any more pearls of wisdom to impart to me before I go and help out another fellow amateur?"

"Only one," I replied. "Make sure that you don't lose your 2 meter signals in your feedline. Coax line can be pretty lossy at that frequency, if you have a long run of the stuff Here's a chart of line loss that can help you in this respect, fig. 4). The big stufl has less loss than the small stuff. Remember that."

Pendergast sighed. "Very well." He moved towards the door as if to slip into the night. "One more topic of conversation. I'm on my way over to a new ham in the neighborhood. Just got his General class license. His name is Larry Lovelace."

"Does he have a sister named Linda?," I asked quickly.

"No, said Pendergast," but he does have an antenna problem. Maybe you can give me an idea or two to take along to him."

"Too bad," I replied. "About the sister, I mean. What's Larry's antenna problem?"

"It's the old story," said Pendergast. He lives in an apartment and wants to get on 40 meters. He has the OK to put an antenna on the roof, but it is very, very small. And a 40 meter antenna is very, very big. See the problem?"

"Very clearly. He should move," I replied.

Pendergast shook his head. "No, no. Can't do that. You'll have to come up with a better idea than that."

"Well, the problem's not a new one," I said. "Lot of fellows have been caught in the