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Breakthrough! A Computerized Antenna Rotator!

—KIM-1 can do!

One evening, Rich WB3CTZ and I were discussing various improvements we had made to our ham shacks which had resulted in greater operating convenience. One thing that we felt still could be improved was the operation of Rich's Ham II rotator. There was no simple way to get around the normal system of looking up the bearing, holding the brake release down while operating the motor control, and watching the bearing indicator. Finally, a decision must be made to release the motor control at the correct time. When this scenario is repeated many times during a contest, it consumes a considerable amount of valuable time. A thirty-hour contest might require as much as one hour of time devoted to operating the antenna (an average of 45 seconds per operation and four operations per hour).

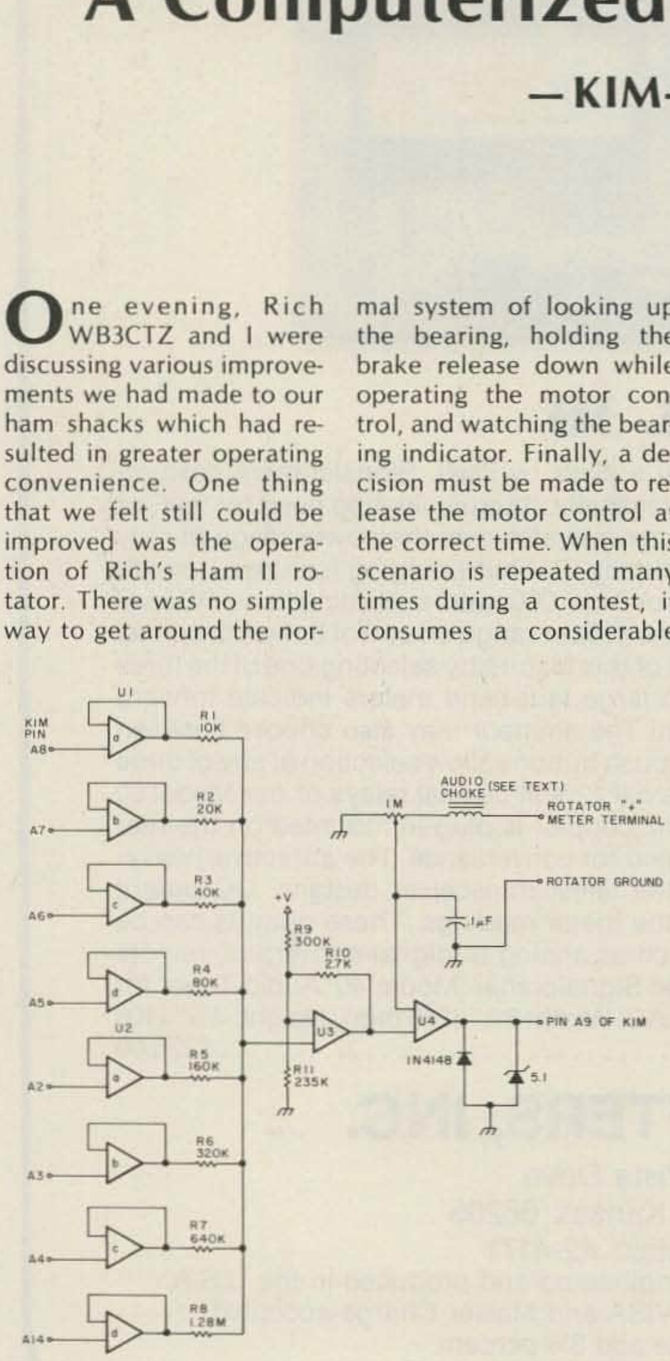


Fig. 1. A/D converter. U1, U2—quad op amp (RS 276-1711); U3, U4—741 op amp.

About this same time, we were trying to come up with a good application for our newly-purchased KIM-1 microprocessor. We had told our wives how great micros were but had not been able to show them much more than the old standby, Lunar Lander. We decided to work out a method of using the KIM to control and operate the Ham II rotator, thereby eliminating two problems at one time, to everyone's delight. The result was so overwhelmingly successful we thought that other hams might benefit from it.

The system we came up with consists of an A/D converter (so that the KIM will be able to read the bearing of the antenna), a relay-operated interface to operate the controls of the rotator, and the software. Operation of the system is very simple. After the program is read into the KIM, a simple calibration is conducted. From then on, the KIM does the work. You punch in the bearing and push the ST (start) key. The KIM will turn on the power to the rotator, operate the brake release, turn on the motor to turn the antenna to the desired heading, turn off the motor at the correct time, wait until the antenna has coasted to a stop, set the brake, and turn off power to the rotator control. At all times the selected bearing is displayed digitally on the KIM display.

There are many error checks and fail-safe devices built into the program to prevent the operator from doing something wrong. All switches in the rotator control unit have been paralleled so that manual operation can be used at any time. The system has been found to be reliable and very accurate. Our initial design goal was an accuracy of two degrees, but as far as we can determine, the antenna stops at the exact bearing punched into the KIM (as indicated by the meter on the Ham II).

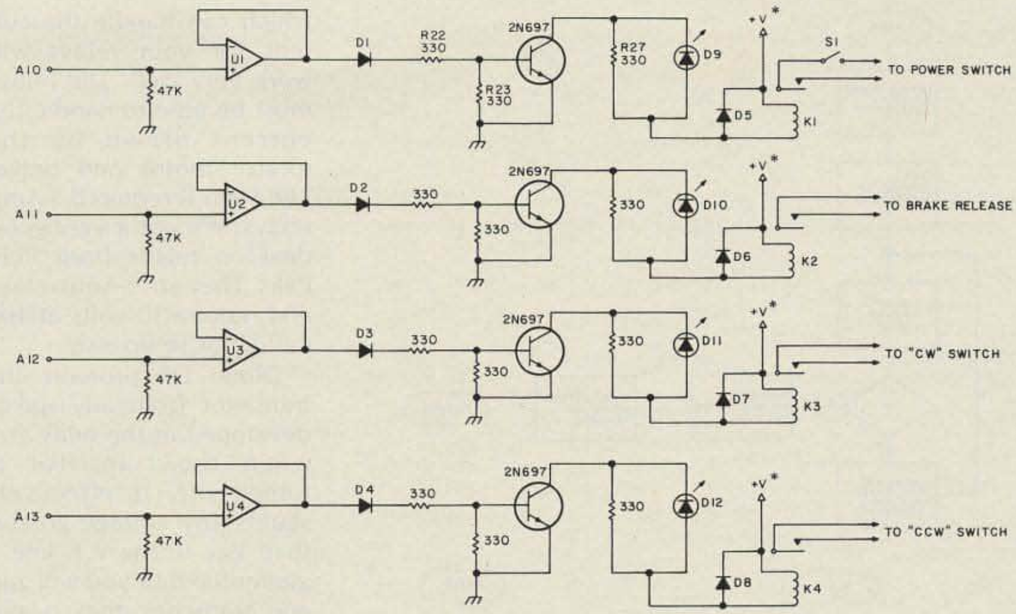


*Fig. 2. Relays and relay driver. U1-U4—741 op amps or equivalent; D1-D8—1N4148; K1-K4—12-V dc relays (see text). *Install on/off switch on V+ line to disable relays.*

The I/O Device

The I/O device is two separate circuits. One is nothing more than a home-brew A/D converter and the other is a number of relays and relay drivers to operate the various controls of the rotator.

The A/D converter in Fig. 1 probably could be replaced with a commercial unit. I took the home-brew route to maintain my image of doing things the hard way. Besides, I thought it would be instructive and rewarding.

Operation of the A/D converter is not difficult. U1, U2, and U3 generate a voltage determined by the digital word at the output of the KIM. The higher the digital word, the higher the voltage generated. U4 compares this voltage to the voltage to be measured from the rotator. When the two voltages are equal, the comparator sends a signal to the KIM (U4 output changes state). The voltage from the rotator is directly proportional to the bearing of the antenna. For the KIM to determine where the antenna is pointing, all it has to do is keep changing the digital word at the input of U1 and U2 until it gets the highsign from the comparator. In our system, what actually happens is that the KIM calculates what the digital word would be for a desired heading and then turns the antenna until the rotator voltage is equal to the voltage generated by the digital word.

U1 and U2 are quad op amps set up as voltage followers. The outputs will follow the digital word at the inputs (0 or 5 volts) and act as a current source. R1 through R8 make up a voltage divider whose output will be somewhere between 0 volts and 5 volts. Since there are eight inputs to the voltage divider, there are 256 different voltages possible which may be generated. Our unit generates voltages with a resolution of 18.35 millivolts between 0 volts and 4.7 volts.

U3 is a summing amplifier for the voltage and also is used to "zero" the system. We found that our KIM produced about 40 millivolts when its outputs were low. This was equivalent to about 3 degrees of antenna rotation. We found that we could compensate for this slight offset using U3 and resistors R9, R10, and R11. The values of these resistors were found experimentally by using potentiometers and adjusting them until the output of U3 was exactly 0 volts when all inputs to U1 and U2 were held low by the KIM. The values shown should work very well with most machines.

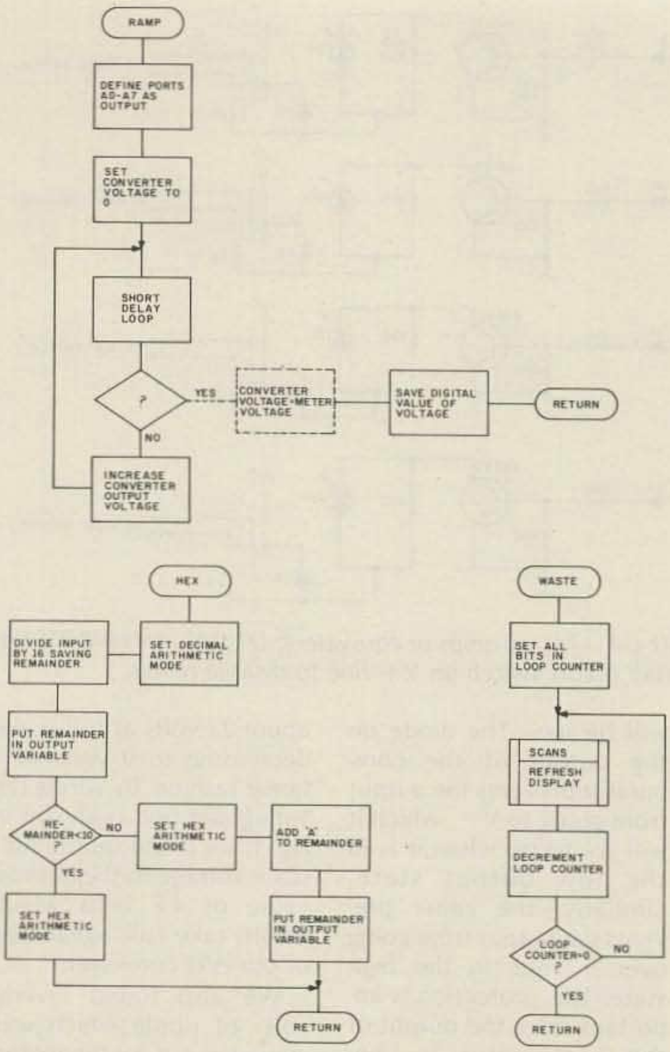
The output of the summing amp is fed to the noninverting input of the comparator, U4. The voltage from the rotator, which is directly proportional to the antenna bearing, is fed to the inverting input of the comparator. Whenever the voltage from the rotator is higher than the voltage generated by the KIM, the output from the comparator will be low. The diode on the output of the comparator prevents the output from going to V−, which it will try to do when it is in the low output state. Similarly, the zener prevents the output from going over 5 volts in the high state. This protection is important since the output of the comparator is connected to the KIM to tell it when the antenna voltage is equal to the voltage generated by the A/D converter.

I recommend checking out the operation of the comparator carefully before hooking it to the KIM to be sure that the voltage does not go above 5 volts or to some negative value. This is the only place in the system where a voltage is fed into the KIM. All other connections are outputs from the KIM.

All connections to the KIM are as shown in Figs. 1 and 2, with the exception of the power supply. The connection to the antenna rotator control is made through the 1-megohm pot wired as a voltage divider and a filter choke to filter 60-cycle hum. We found that the voltage across the meter in the Ham II was about 22 volts at full scale, decreasing to 0 volts in a linear fashion. By wiring the 1-megohm pot as shown in Fig. 1, we could set the full-scale voltage to the desired value of 4.7 volts which would take full advantage of our A/D converter.

We also found several volts of ripple which was averaged out by the meter. To eliminate this ripple, we used the choke-capacitor filter shown in Fig. 1. The choke came from a "boat anchor" in the basement and probably any audio-type choke will be sufficient. A slight amount of hum at the input to the comparator will cause the KIM to turn off the rotator motor early regardless of the direction in which the antenna is turning. Each 13 millivolts of ripple is equivalent to one degree of rotation. In our unit, the ripple is small enough that the antenna comes to rest at just the right place. Murphy must have been out to lunch the day we chose our choke!

The four relay driver circuits shown in Fig. 2 are identical. One is for the on/off switch, one for the brake switch, and one each for the two motor switches.



Subroutine flowcharts.

As the relay drivers operate similarly, I will describe only the one used for the power switch. The output from the KIM is hooked to the non-inverting input of buffer amplifier U1, a 741 op amp, wired as a voltage follower. The 47k-Ohm resistor from the input of the buffer to ground will keep stray signals and noise from activating the relays. Without these resistors, we found that a 2-microamp signal would operate the circuit and trigger the relays. The output of the buffer amp is fed through diode D1 to the transistor, which operates as a switch. D1 will not conduct until it is forward biased to .7 volts. This is necessary to prevent relay activation from the 40-millivolt potential at the output of the KIM when it is in the low state.

Resistors R22 and R23 limit the current drawn from the buffer amp and bias the transistor to operate as a switch. I used 330-Ohm resistors since I had quite a few on hand, although other values would work just as well. The transistors are junk-box specials. Any NPN transistor with a gain of 30 or more which can handle the current for your relays will work very well. The relays must be able to handle the current drawn by the rotator motor and brake. The Ham II required 5-Amp relays. We got a very good deal on relays from Poly Paks. They are 5-Amp relays and require 10 volts at 100 milliamps to operate.

Delay	Location
Power on to brake release	02C6
Brake release to rotation	02D6
Stop rotation to apply brake	0322
Apply brake to power off	0332

Table 1. Rotator timing delays.

Diode D5 protects the transistor from any spikes developed in the relay coil when the transistor is turned off. It effectively shunts any voltage greater than Vcc to the V+ line. I guarantee that you will zap any transistor that is not protected by such a diode.

LED D9 and resistor R27 may be omitted and the relay hooked directly to the collector of the transistor. We had it set up without these two parts at first, but found it very unnerving to hear the relays clicking and not know which ones or exactly what was happening. The LED will turn on when the relay is energized, indicating which relay is operating. This is particularly helpful in system checkout and troubleshooting.

The final item I want to mention is the switch, S1. It is used to disable the on/off relay during calibration, initialization, and troubleshooting. Remember that this switch and relay are switching 120 V ac, so *extreme caution should be exercised*. The entire on/off power switch relay can be eliminated from the system if you so wish, but you will have to leave the power turned on to the rotator control all the time. Another switch should be provided in the V+ which goes to the relay transistors so that all relays can be disabled for calibration. This switch should be left open until calibration is complete.

The Software

With the hardware under way, we began work on the computer program. The first step was to determine how to tell the computer how far the antenna could be turned in either direction. To do this, we came up with the following method. We first turned the antenna as far as possible in a counterclockwise direction, entered the number 1000 into the computer, and pressed the ST key. (The 1000 should appear on the address LEDs of the KIM.) The computer interpreted this action and read the bearing on the rotator. This number became the extreme for counterclockwise rotation.

The extreme for clockwise rotation was indicated to the computer by swinging the beam as far as possible in the clockwise direction, entering the number 2000, and pressing the ST key. (These two actions can be done in either order.) Once the extremes of rotation are determined, the operator enters the number 3000 and presses the ST key, thus telling the computer to set all its internal math calculations based on the two extremes of rotation. If you get clockwise and counterclockwise mixed up, the computer will tell you by displaying Es when the 3000 command is entered. We call these steps calibration, and they must be done before the computer can recognize properly any commands to turn to a certain bearing.

After the calibration stage, the operator may enter any bearing, followed by ST, and the computer will do its job. It will—

1) Turn on ac power to the rotator

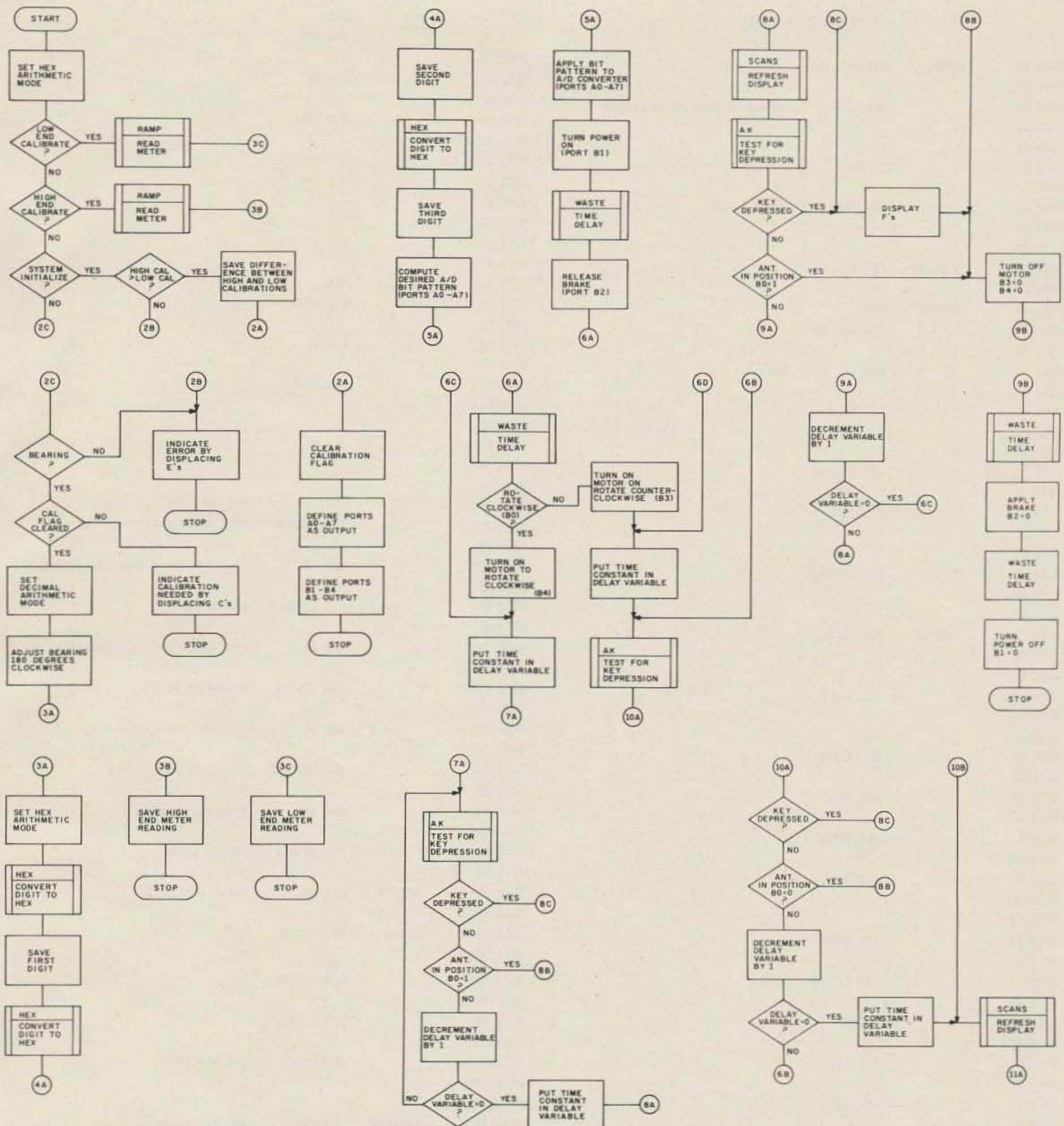
2) Release the brake

3) Turn the antenna to the desired bearing

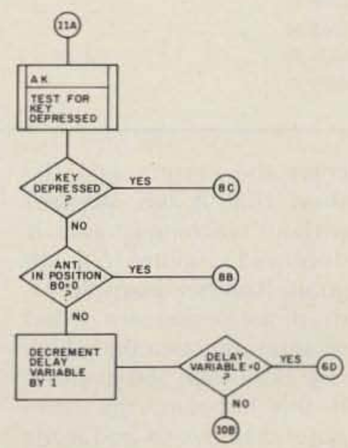
4) Reapply the brake

5) Turn off ac power to the control box

During the time that the antenna is in motion, the



Flowchart.



bearing which was entered by the operator will flash. When the flashing stops, the antenna is in position. A side benefit of this system is that a digital readout of the current antenna position will be shown whenever the antenna is not in motion.

Although the computer is always right, there are some errors which we humans may make. One is attempting to enter a bearing before performing the calibration steps. If we do this, the computer displays Cs, telling us that it will not respond because no calibration has been done. Another is entering a bearing which is not really the one we want and noticing it after the computer begins moving the antenna. We can either wait for the antenna to reach the wrong position and then enter the one we really wanted, or we can touch any key on the keyboard. When any key is touched during rotation, the computer assumes that we entered the wrong bearing and stops the antenna where it is so that we can

Program listing.

```
0020 A9   RAMP      LDA FF
0021 FF
0022 8D             STA 1701      define A0 thru A7 as output
0023 01
0024 17
0025 A9             LDA 00
0026 00
0027 8D             STA 1700      clear output
0028 00
0029 17
002A A0   LTRYAGN   LDY 10
002B 10
002C 88   LOOP10    DEY
002D D0             BNE LOOP10
002E FD
002F A9             LDA 01        test bit
0030 01
0031 2C             BIT 1702
0032 02
0033 17
0034 D0             BNE LGOTIT
0035 05
0036 EE             INC 1700
0037 00
0038 17
0039 4C             JMP LTRYAGN
003A 2A
003B 00
003C AD   LGOTIT    LDA 1700
003D 00
003E 17
003F 85             STA VRAMP
0040 09
0041 60             RTS
0050 A5             LDA VBSVH
0051 08
0052 E9             SBC 00
0053 00
0054 85             STA VBSVH
0055 08
0056 4C             JMP 3A1
0057 A1
0058 03
0059 85             STA VWORK1
005A 0C
005B A5             LDA VWORK2
005C 0D
005D E9             SBC 00
005E 00
005F 85             STA VWORK2
0060 0D
0061 4C             JMP 233
0062 33
0063 02
0064 A2             LDX FF
0065 FF
0066 CA   AGN       DEX
0067 D0             BNE AGN
0068 FD
0069 A9             LDA 01
006A 01
006B 2D             AND 1702
006C 02
006D 17
006E 4C             JMP 2FB
006F FB
0070 02
0071 A2             LDX FF
0072 FF
0073 CA             DEX
0074 D0             BNE AGN1
0075 FD
0076 A9             LDA 01
0077 01
0078 D2             AND 1702
0079 02
007A 17
007B 4C             JMP 363
007C 63
007D 03
0200 D8             CLD           set hex mode
0201 A5             LDA POINTH    high order characters
0202 FB
0203 C9             CMP 10        test for low end calibration
0204 10
0205 F0             BEQ LCALLOW   branch if so
0206 17
0207 CA             CMP 20        test for high end calibration
0208 20
0209 F0             BEQ LCALHI    branch if so
020A 1D
020B C9             CMP 30        test for set calibration
020C 30
020D F0             BEQ LSETCAL   branch if so
020E 23
020F C9             CMP 04        test for bearing
0210 04
0211 90             BCC LBEAR     branch if so
0212 39
0213 A9   LERROR    LDA EE        error code
0214 EE
0215 85   DISP      STA POINT
0216 F9
0217 85             STA POINTL
0218 FA
0219 85             STA POINTH
021A FB
021B 4C             JMP START     display error
021C 4F
021D 1C
021E 20   LCALLOW   JSR RAMP      get I/O value
021F 20
0220 00
0221 A5             LDA VRAMP     low end I/O value
```

enter the correct one. To show that it has stopped without reaching its goal, it displays Fs (failure to reach goal). Another possible error of major concern is that of entering a bearing which is greater than 360 degrees. If this happens, the computer displays Es and waits for a proper entry. The Es also will be displayed if we try to enter a command which it does not recognize (e.g., 5000 instead of 3000).

After the program is read into the computer, the following steps must be taken before the ST key will function. Place the values 00 and 02 in core locations 17FA and 17FB respectively. *This should be done immediately after the program is loaded into the computer.*

Most of the program is straightforward. However, some complexity was involved in determining when the antenna had reached the desired bearing. The approach taken to this problem was to have the microprocessor calculate and generate through the A/D converter a voltage corresponding to the desired bearing. The antenna is then rotated until the voltage from the rotator equals

```
0222 09
0223 85                STA VLOWEND   save it
0224 00
0225 4C                JMP START     exit
0226 4F
0227 1C
0228 20      LCALHI    JSR RAMP      get I/O value for high end
0229 20
022A 00
022B A5                LDA VRAMP
022C 09
022D 85                STA VHIEND    save it
022E 01
022F 4C                JMP START     exit
0230 4F
0231 1C
0232 A5      LSETCAL   LDA VHIEND    high calibration value
0233 01
0234 38                SEC           set for subtract
0235 E5                SBC VLOWEND   subtract low calibration value
0236 00
0237 90                BCC LERROR    error if values reversed
0238 DA
0239 85                STA VCALCONST save difference
023A 02
023B A9                LDA 00        clear A
023C 00
023D 85                STA VCALFLAG  indicate calibration completed
023E 03
023F A9                LDA FF
0240 FF
0241 8D                STA 1701      set A0 thru A7 as output
0242 01
0243 17
0244 A9                LDA 1E
0245 1E
0246 8D                STA 1703      set B1 thru B4 as output
0247 03
0248 17
0249 4C                JMP START     exit
024A 4F
024B 1C
024C A5      LBEAR     LDA POINTL    low order bearing
024D FA
024E 38                SEC           prepare for subtract
024F F8                SED           set decimal mode
0250 E9                SBC 61        check for illegal bearing
0251 61
0252 A5                LDA POINTH
0253 FB
0254 E9                SBC 03
0255 03
0256 B0                BCS LERROR    report if bearing bad
0257 BB
0258 A5                LDA VCALFLAG  check for calibration performed
0259 03
025A F0                BEQ LCALDNE
025B 05
```

```
025C A9      LCAL      LDA CC
025D CC
025E 4C                JMP DISP
025F 15
0260 02
0261 4C                JMP 3C3
0262 C3
0263 03
0267 85                STA VBSVL
0268 07
0269 20                JSR HEX       convert to hex
026A 93
026B 03
026C A5                LDA VREM
026D 0A
026E 85                STA VHEXBRL   first digit
026F 0B
0270 20                JSR HEX
0271 93
0272 03
0273 06                ASL VREM      position second digit
0274 0A
0275 06                ASL VREM
0276 0A
0277 06                ASL VREM
0278 0A
0279 06                ASL VREM
027A 0A
027B 18                CLC
027C A5                LDA VHEXBRL
027D 0B
027E 65                ADC VREM
027F 0A
0280 85                STA VHEXBRL   place second digit
0281 0B
0282 20                JSR HEX       third digit
0283 93
0284 03
0285 66                ROR VREM
0286 0A
0287 66                ROR VHEXBRL   this is input in hex
0288 0B                              divided by 2
0289 A5                LDA VHEXBRL   compute A/D bit pattern
028A 0B
028B 85                STA VWORK1
028C 0C
028D A9                LDA 00
028E 00
028F 85                STA VWORK2
0290 0D
0291 A6                LDX VCALCONST
0292 02
0293 F0                BEQ LCAL      calibrate if constant equals zero
0294 C7
0295 CA      LOOP3     DEX
0296 F0                BEQ LDIV      branch if multiply complete
0297 10
0298 18                CLC           set for add
```

the voltage generated by the A/D converter. At this point, the antenna is pointing in the desired direction.

The first step in this process was to find an algorithm for computing the correct voltage for a given bearing. My rotator is set so that zero degrees is exactly mid-scale, with 180 degrees found at either extreme. To develop a linear correspondence between the bearing and the rotator voltage, it was first necessary to add 180 degrees to the input bearing. This calculation causes the lowest voltage to correspond to the smallest bearing figure after the addition. Since the A/D converter works in 256 steps across its range, we theoretically could find the proper bit pattern for generation of the bearing's voltage by using this formula: 255/360 × input bearing = bit pattern.

The only problem with this approach is that the lowest voltage generated by the A/D converter might not equal the lowest voltage from the rotator. Likewise, the highest voltages might not be equal. Compensation for this factor is included in the calculation. When the value 1000 is en-

```
0299 A5           LDA VWORK1
029A 0C
029B 65           ADC VHEXBRL
029C 0B
029D 85           STA VWORK1
029E 0C
029F A5           LDA VWORK2
02A0 0D
02A1 69           ADC 00
02A2 00
02A3 85           STA VWORK2
02A4 0D
02A5 4C           JMP LOOP3
02A6 95
02A7 02
02A8 A2   LDIV    LDX 00        clear for divide
02A9 00
02AA 38   LOOP4   SEC
02AB A5           LDA VWORK1
02AC 0C
02AD E9           SBC B4
02AE B4
02AF'4C           JMP 59
02B0 59
02B1 00
02B3 90           BCC LBDONE
02B4 04
02B5 E8           INX
02B6 4C           JMP LOOP4
02B7 AA
02B8 02
02B9 8A   LBDONE  TXA
02BA 18           CLC
02BB 65           ADC VLOWEND
02BC 00
02BD 8D           STA 1700      desired voltage
02BE 00
02BF 17
02C0 A9           LDA 02        power on
02C1 02
02C2 8D           STA 1702      turn on box
02C3 02
02C4 17
02C5 A9           LDA 08
02C6 08
02C7 85           STA VTIME     waste time
02C8 0E
02C9 20   LWASTE1 JSR WASTE
02CA 84
02CB 03
02CC C6           DEC VTIMER
02CD 0E
02CE D0           BNE LWASTE1
02CF F9
02D0 A9           LDA 06
02D1 06
02D2 8D           STA 1702      release brake
02D3 02
02D4 17
02D5 A9           LDA 04
02D6 04
02D7 85           STA VTIMER    waste time
02D8 0E
02D9 20   LWASTE2 JSR WASTE
02DA 84
02DB 03
02DC C6           DEC VTIMER
02DD 0E
02DE D0           BNE LWASTE2
02DF F9
02E0 A9           LDA 01        test bit
02E1 01
02E2 2D           AND 1702      check for left or right
02E3 02
02E4 17
02E5 F0           BEQ LRIGHT    rotate right
02E6 68
02E7 A9           LDA 0E        left motor
02E8 0E
02E9 8D           STA 1702      turn on motor
02EA 02
02EB 17
02EC A9   LMOTOR1 LDA FF
02ED FF
02EE 85           STA VWASTE1
02EF 0F
02F0 20   LOOP5   JSR AK
02F1 FE
02F2 1E
02F3 AA           TAX
02F4 D0           BNE LFAIL
02F5 4E
02F6 4C           JMP 64        test bit
02F7 64
02F8 00
02FB F0           BEQ LOFF
02FC 1F
02FD C6           DEC VWASTE1
02FE 0F
02FF D0           BNE LOOP5
0300 EF   you have now punched in about half of the program!!!
0301 A9           LDA 50
0302 50
0303 85           STA VWASTE1
0304 0F
0305 20   LOOP6   JSR SCANS     refresh display
0306 1F
0307 1F
0308 20           JSR AK
0309 FE
030A 1E
030B AA           TAX
030C D0           BNE LFAIL
030D 36
```

tered into the computer, it generates a series of voltages, beginning with the least possible voltage and stopping when the generated voltage is equal to the rotator voltage. Since at this time the meter should be at its lowest point, as set by the operator, we have the bit pattern representing this position. The same is true for the high end of the meter operation. When the value 2000 is entered, the same series of voltages is generated by the computer, stopping when the generated value is equal to the sample from the rotator. We then have a bit pattern representing the highest point of meter movement. By subtracting these two values, we find a value, K, which we can use in the following formula: K/360 × input bearing = X.

When the value X from this formula is added to the bit pattern representing the lowest point of meter movement, a bit pattern representing the desired bearing results. This pattern can then be applied to the A/D converter and the rotator stopped when the sample voltage from the meter becomes equal to the voltage generated by the converter. Since I/O port B0 is connected to the output of a comparator which com-

```
030E A9            LDA 01        test bit
030F 01
0310 2D            AND 1702
0311 02
0312 17
0313 F0            BEQ LOFF      shut off if voltage OK
0314 07
0315 C6            DEC VWASTE1
0316 0F
0317 D0            BNE LOOP6
0318 EC
0319 4C            JMP LMOTOR1
031A EC
031B 02
031C A9   LOFF     LDA 06
031D 06
031E 8D            STA 1702      shut off motor
031F 02
0320 17
0321 A9            LDA 10
0322 10
0323 85            STA VTIMER
0324 0E
0325 20   LWASTE3  JSR WASTE     waste time
0326 84
0327 03
0328 C6            DEC VTIMER
0329 0E
032A D0            BNE LWASTE3
032B F9
032C A9            LDA 02
032D 02
032E 8D            STA 1702      apply brake
032F 02
0330 17
0331 A9            LDA 04
0332 04
0333 85            STA VTIMER
0334 0E
0335 20   LWASTE4  JSR WASTE     waste time
0336 84
0337 03
0338 C6            DEC VTIMER
0339 0E
033A D0            BNE LWASTE4
033B F9
033C A9            LDA 00
033D 00
033E 8D            STA 1702      power down box
033F 02
0340 17
0341 4C            JMP START     exit
0342 4F
0343 1C
0344 A9   LFAIL    LDA FF        fail code
0345 FF
0346 85            STA F9
```

```
0347 F9
0348 85            STA FA
0349 FA
034A 85            STA FB
034B FB
034C 4C            JMP DISP      display fail code
034D 1C
034E 03
034F A9   LRIGHT   LDA 16        right motor
0350 16
0351 8D            STA 1702
0352 02
0353 17
0354 A9   LMOTOR2  LDA FF
0355 FF
0356 85            STA VWASTE1
0357 0F
0358 20   LOOP7    JSR AK
0359 FE
035A 1E
035B AA            TAX
035C D0            BNE LFAIL
035D E6
035E 4C            JMP 71        test bit
035F 71
0360 00
0363 D0            BNE LOFF
0364 B7
0365 C6            DEC VWASTE1
0366 .0F
0367 D0            BNE LOOP7
0368 EF
0369 A9            LDA 50
036A 50
036B 85            STA VWASTE1
036C 0F
036D 20   LOOP8    JSR SCANS     refresh display
036E 1F
036F 1F
0370 20            JSR AK
0371 FE
0372 1E
0373 AA            TAX
0374 D0            BNE LFAIL
0375 CE
0376 A9            LDA 01        test bit
0377 01
0378 2D            AND 1702
0379 02
037A 17
037B D0            BNE LOFF      shut off if voltage OK
037C 9F
037D C6            DEC VWASTE1
037E 0F
037F D0            BNE LOOP8
0380 EC
0381 4C            JMP LMOTOR2
```

pares the sample voltage from the rotator with the voltage generated by the A/D converter, examination of the port determines the direction of rotation. In this case, a value of 0 indicates that counterclockwise rotation is needed until that port becomes a 1. If 1 is the original value, then clockwise rotation is needed until that port changes to a value of 0.

Another problem to be considered is that the KIM is much faster at issuing requests to the electronic devices than those devices are at accepting the commands. For example, the computer could issue I/O to release the brake and then issue I/O to turn on the motor long before the mechanical action of removing the brake was completed. To adjust for this type of situation, we placed various delay loops in the program. Some of these may be of interest because the length of each delay was arbitrarily selected. Table 1 lists the addresses which can be modified to change the various time delays which apply to the rotator controls. Placing a higher value in any of these locations will increase the time delay, while a smaller value will decrease the delay.

```
0382 54
0383 03
0384 A9    WASTE    LDA FF         waste time
0385 FF
0386 85             STA VWASTE 3
0387 11
0388 85    LOOP10   STA VWASTE2
0389 10
038A 20    LOOP9    JSR SCANS
038B 1F
038C 1F
038D C6             DEC VWASTE3
038E 11
038F D0             BNE LOOP9
0390 F9
0391 60             RTS
0393 F8    HEX      SED            compute one hex digit
0394 A2             LDX 00
0395 00
0396 38    LSUB     SEC
0397 A5             LDA VBSVL
0398 07
0399 E9             SBC 16
039A 16
039B 85             STA VBSVL
039C 07
039D 4C             JMP 50
039E 50
039F 00
03A1 90             BCC LADD
03A2 08
03A3 8A             TXA
03A4 18             CLC
03A5 69             ADC 01
03A6 01
03A7 AA             TAX
03A8 4C             JMP LSUB
03A9 96
03AA 03
03AB 4C    LADD     JMP 3EE
03AC EE
03AD 03
03AE 86             STX VBSVL
03AF 07
03B0 85             STA VREM
03B1 0A
03B2 38             SEC
03B3 E9             SBC 10
03B4 10
03B5 30             BMI LRET
03B6 06
03B7 D8             CLD
03B8 18             CLC
03B9 69             ADC 0A
03BA 0A
03BB 85             STA VREM
03BC 0A
03BD D8    LRET     CLD
03BE A9             LDA 00
03BF 00
03C0 85             STA VBSVH
03C1 08
03C2 60             RTS
03C3 A5             LDA POINTL
03C4 FA
03C5 18             CLC
03C6 F8             SED
03C7 69             ADC 80
03C8 80
03C9 85             STA VPTL
03CA 12
03CB A5             LDA POINTH
03CC FB
03CD 69             ADC 01
03CE 01
03CF 85             STA VPTH
03D0 13
03D1 38             SEC
03D2 A5             LDA VPTL
03D3 12
03D4 E9             SBC 60
03D5 60
03D6 85             STA VWORK1
03D7 0C
03D8 A5             LDA VPTH
03D9 13
03DA E9             SBC 03
03DB 03
03DC 90             BCC LRDY
03DD 06
03DE 85             STA VPTH
03DF 13
03E0 A5             LDA VWORK1.
03E1 0C
03E2 85             STA VPTL
03E3 12
03E4 D8    LRDY     CLD
03E5 A5             LDA VPTH
03E6 13
03E7 85             STA VBSVH
03E8 08
03E9 A5             LDA VPTL
03EA 12
03EB 4C             JMP 267
03EC 67
03ED 02
03EE A5             LDA VBSVL
03EF 07
03F0 18             CLC
03F1 69             ADC 16
03F2 16
03F3 4C             JMP 3AE
03F4 AE
03F5 03
```

Power Supply

The power supply we used for the KIM was the same one that was supplied with the unit when we purchased it. For the I/O devices, we used a dual-polarity adjustable bench supply that I normally use to operate the various projects in the ham shack. We set the supply to plus and minus 9 volts. A more permanent supply can be constructed but it must be regulated and must be dual polarity. This can be done easily with two 9-volt regulator chips. The minus regulator needs to supply about 50 milliamps, but the positive regulator must be able to operate the relays, and about 250 milliamps was satisfactory in our unit.

Although this unit was sufficient for our purposes, an ASCII keyboard and 4K of memory could be added to the system. A bearing table for DX calls could be placed in the additional memory. By entering the call prefix, the computer could be directed to look up the proper bearing and automatically rotate the antenna. By including more data in the bearing table, the computer could even display the approximate distance to the DX station. ■