A+

DESIGN AND CONSTRUCTION

OF A

CODE GENERATOR

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INTRODUCTION

The keyboard keyer is an electronic typewriter machine capable of sending single letters at a time in International Morse Code with a perfection unmatched by earlier generators. The state of the art went from the simple hand key to bugs and side-swipers and then on to electronic keyers through the 1950's that could make a series of dots or dashes automatically. These designs came primarily from the amateur ranks because the military transmitters required the switching of several amperes of current with their high powered transmitters. They still primarily use the hand key for their CW transmissions.

With advanced computer techniques of the 1960's the stage was set for the keyboard keyer, the keyer with a memory. The first keyboard keyer was built in 1957 using relays for the memory and logic sections. Both electrically and mechanically it lacked much to be desired though and never was very popular. In 1965 a keyboard keyer appeared in August QST magazine that used ferrite cores for the memory and transistors throughout the rest of the circuit. Its performance was excellent but the unit was larger than necessary.

Recognizing that the integrated circuit packages available today would considerably reduce the size of the unit, with fewer circuit problems, an attempt was made at redesigning and building the keyer. The unit was completed and works satisfactorily. By typing, Morse code can be smoothly sent ten through sixty or more words per minute. At the moment it represents the state of the art for electronic keyers.

LOGIC DESIGN

The design of the circuit had to meet these requirements:

(1) A dash was to be three dot lengths.

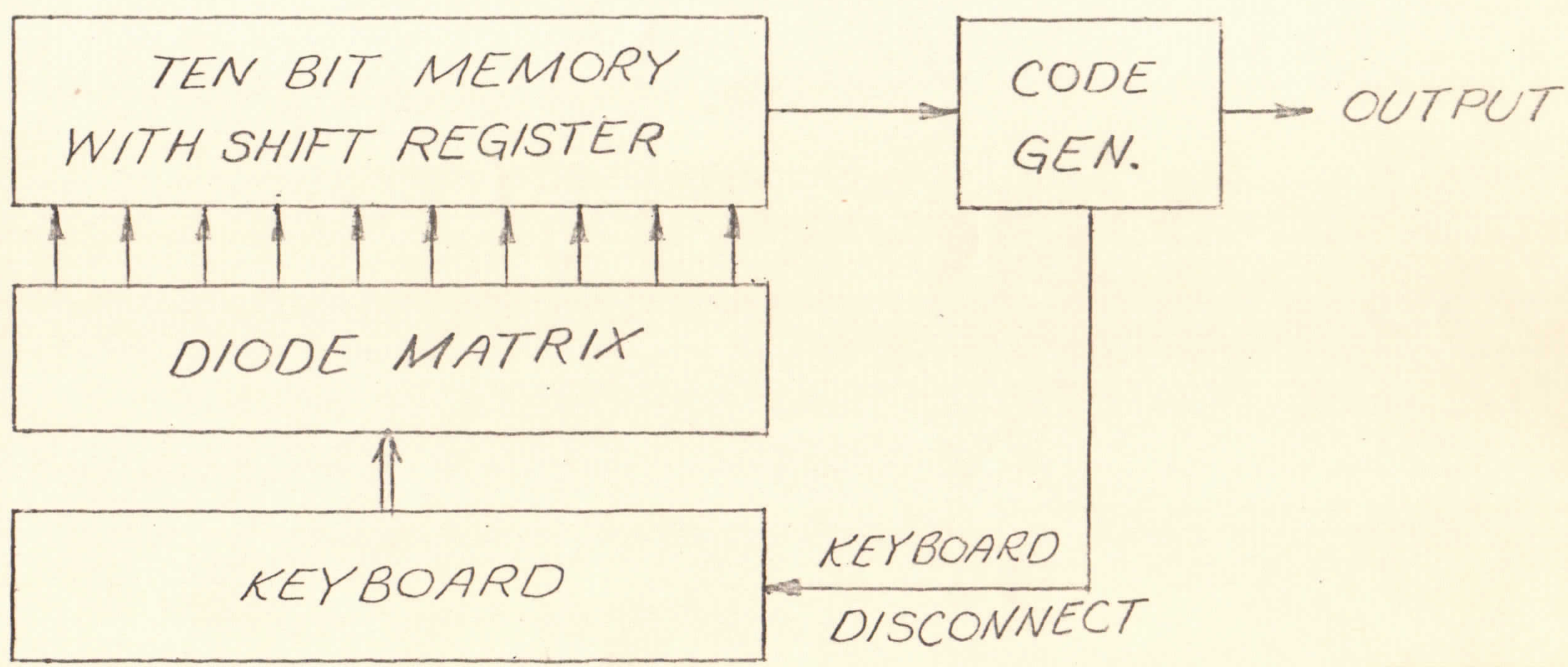
(2) An off period of one dot length was to separate each on period within a letter.

(3) And an off period of three dot lengths was to separate each different letter sent.

It seemed obvious that digital techniques would fill all the three conditions above. A master clock in the keyer runs at a constant frequency and controls every operation with precise timing.

The keyboard keyer consists of four main sections. As shown in Figure 1, they are the keyboard, the diode matrix, the ten bit memory, and the code generator. The diode matrix is the interconnecting network between the keyboard and memory and is used to load the memory with the correct information for a specific letter. Pressing a key will load the memory and immediately thereafter disconnect the keyboard to prevent the memory from becoming confused. The memory is connected as a shift register and shifts the information into the

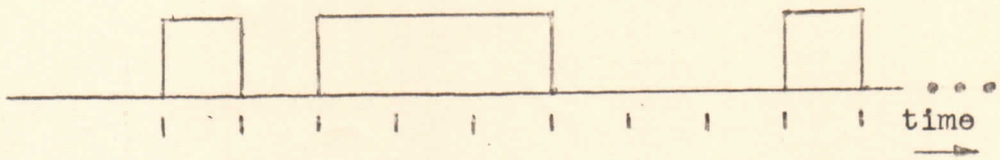
FIG. 1 BASIC FUNCTIONS



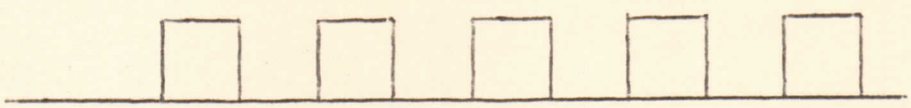
code generator at a clocked rate. The code generator then keys the transmitter at a rate determined solely by the clock rate.

Now, for a detailed analysis of the circuit operation, refer to Figures 2 and 3. Figure 2 represents the correct transmission of the letter A. Figure 3 is the keyer schematic shown with the standard military symbols for a positive logic system. B(-) is considered to be the zero level and B(+) the one level. If Q of FF13 is high, then the keyboard is on, and pressing the A letter will put 'ones' on FF's 8 and 10. A low input to the reset terminal of these flip-flops will set $\overline{Q}$ high. This will immediately trigger the 10 microsecond one-shot multivibrator and turn off the keyboard 10 microseconds later. The instant $\overline{Q}$ of FF12 goes low the two microsecond one-shot is triggered and sets $\overline{Q}$ of FF14 low if anything is in the memory. This forward biases the 2N4888 output keying transistor. When the output of the 2us one-shot goes high again, the information in the memory is shifted to the left. The ones that were in FF's 8 and 10 have now been moved to FF's 9 and 11 respectively. The transmitter is now turned on and remains on until Q of FF12 goes low. This sets $\overline{Q}$ high again

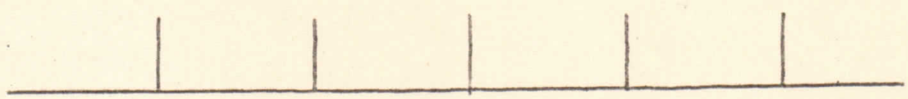
Figure 2. Timing sequence in the generation of the letter 'A'.



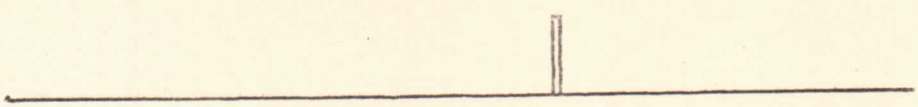
The letter A



Output of Q from FF12, the clock



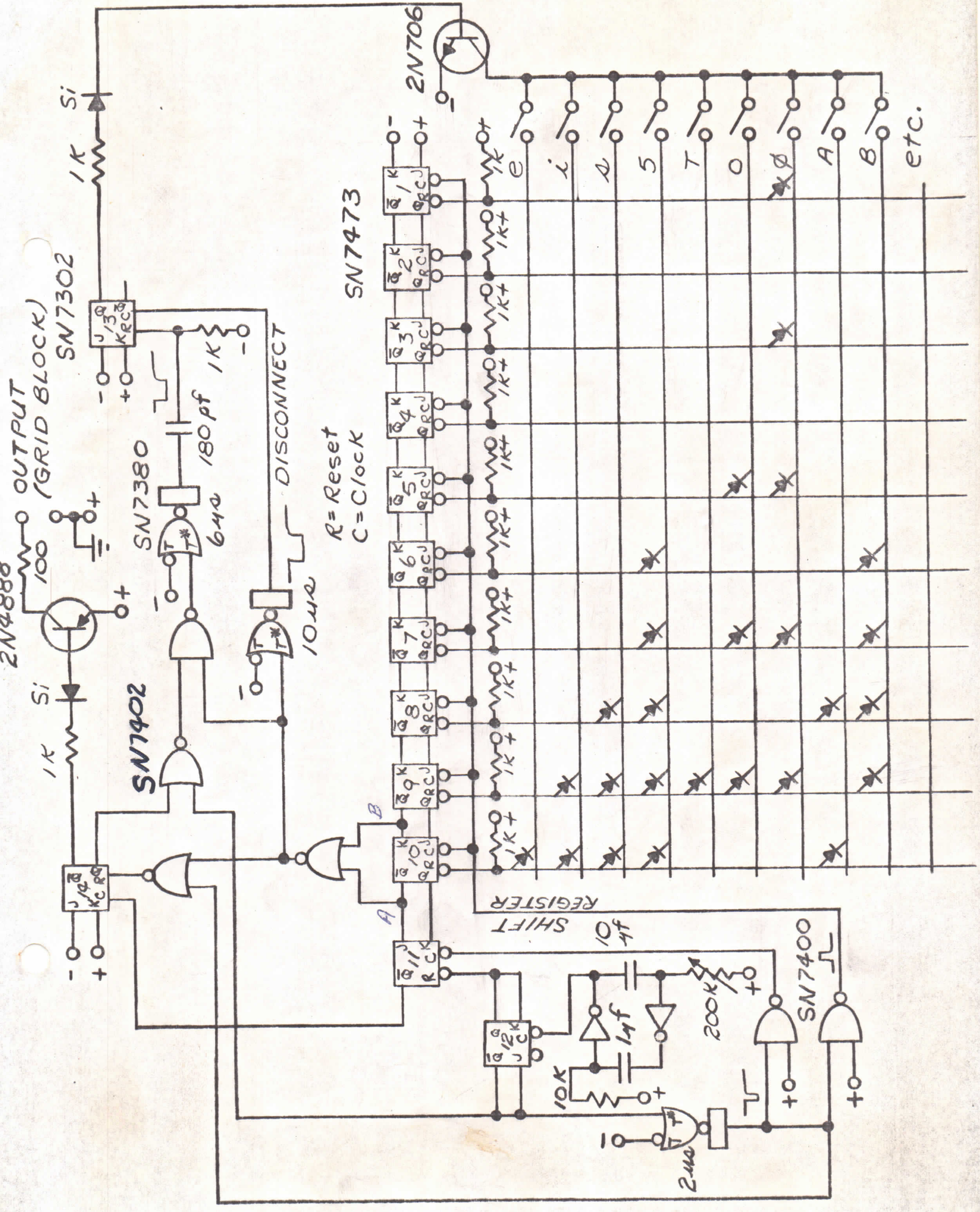
The shift register pulse train



The keyboard reconnect pulse from Q of FF13

Only the first dot and dash represent the letter A. The next dot is the beginning of a new letter. Notice that the requirements for the correct transmission of a letter are met.

Figure 3.



2N706
SN7473
SN7302
OUTPUT (GRID BLOCK)
2N4888
SN7380
SN7402
180 pf
6 μs
10 μs
DISCONNECT
R = Reset
C = Clock
SHIFT REGISTER
SN7400
200K
10K
10 μf
1 μf
2 μs
Si
1K
100
etc.

and that in turn sets $\overline{Q}$ of FF14 high, turning off the output transistor. This completes the first dot in the letter A. With a one still in FF9 the whole process of turning the transmitter on and shifting in the memory occurs again as it did the first time. The main difference in the operation this time though is that the one in FF9 is not directly shifted to FF11, but is delayed for two dit spaces. If no one appears in FF11 the transmitter will not be turned off on any pulse from the clock. The resetting of FF11 back to the zero state completes the generation of the dash. Now the memory is empty and the transmitter is turned off. However the keyboard cannot be reconnected yet because doing so would cause another transmission of a letter with only one dit space between the letters.

The six microsecond one shot multivibrator is the one that reconnects the keyboard. It will be triggered only when (1) the memory is empty, (2) the transmitter is turned off, (3) and $\overline{Q}$ of FF12 goes low. However this was the trigger signal for the two microsecond one shot or shift register pulse. Now it is clear that the keyboard is reconnected four microseconds after the shift occurs. This means that anything read into the memory cannot turn the transmitter on sooner than three dit spaces after the generation of the last letter. Had the shift register delay been longer than the keyboard reconnect, then there would have been only one dot spacing between the letters.

Notice that a one level will be in FF's 9 or 10 if there is a one anywhere in the memory since a dash is the longest symbol transmitted. To generate a successive string of dots, diodes are put on each FF in the memory starting from FF10 and going back down the line until the number of diodes used equals the number of dots wanted. To generate a dash preceding FF's are skipped. The letter 'O' skips FF10 and a diode is put on FF9 for a single dash. Using this idea of the diode arrangements, any combination of dots and dashes can be generated as a single letter.

CONSTRUCTION DETAILS

Since no one is manufacturing a keyboard keyer at the present time everything used on this keyer is completely of the homebrew type construction except the basic components such as the keytops and integrated circuits. The circuit board had to be constructed after the design stage was completed. Two routes were possible here in the layout. Either a printed circit board or sockets with the associated wiring could be used. The printed circuit board was chosen.

Now, to get the board finished, a layout of the circuit was done with the appropriate Texas Instruments data sheets at hand, with black tape circles and strips that were carefully put on a white piece of cardboard. The complexity of the circuit required that both the top and bottom of the PCB would have to be used. The top side and bottom side were correctly laid out at twice the final board size by sticking straight pins through the two pieces of cardboard while they were taped back to back.for corresponding holes and pin locations. After the layout was checked many times for errors, two line negatives were made of them by the Reproduction office here at the university. All that remained now was to photographically etch the board using the negatives. After the board was well cleaned in acid, a coating of photographic resist known as KPR was applied to each side of the board and then baked on for a few minutes. Very tiny holes were then drilled in the negatives and circuit board to assure the correct alignments. Then a contact print was made on the board by holding it in sunlight for a full minute on each side. After washing off the excess KPR in their developer solution, the board was put in a bath of concentrated nitric acid. After about five minutes in the acid all the unexposed copper had been etched off the glass board. Then the holes were drilled and the components were mounted and soldered into place. The board was working properly about two weeks before the case and keytop switches were completed.

Since fiberglas could be easily molded into the shape of a typewriter case, it was chosen as the material for this case. The resin and glass cloth were applied around a balsa wood mold until it was sufficently strong.

The keyboard switches and keytops were integrated into the case as it was being constructed. Each keytop is connected to a short spring lever with a sheet metal screw. Pressing the keytop bends the spring down enough to touch another screw top which completes the other side of the switch.

The common side of all the switches is the spring material since it is merely soldered to another copper clad board, the one that was integrated into the case. The holes for the keytops were first drilled to as large a size possible with a bit and then enlarged into the oval shape required with a round file. There are about fifty holes and this was the most time consuming part of the whole keyer.

There was a considerable amount of wiring that had to be done between the keyboard switches and the printed circuit board. Teflon insulated wire was obtained from the Collins Radio Company surplus store for a few cents.

There were thirteen integrated circuits and 204 silicon diodes used in the keyer. Had these units been purchased directly from the Texas Instruments Company the price for them would have been over 300 dollars. However I was able to find the integrated circuits and diodes I needed to build the unit while working there during the summer of 1968.

The keytops were the most expensive single item, costing ten cents per letter. An estimate on the total price of the keyer would probably come close to twenty or thirty dollars out of my pocketbook.

CONCLUSIONS

Stating again in a compact form, the advantages of the keyboard keyer and reasons for building it are:

(1) The keyboard keyer represents the state of art with digital techniques and integrated circuits.

(2) Using integrated circuits reduced the package size and the power requirements.

(3) The generation of perfect code at a person's fingertips with only a small effort even at high speeds entices even the most indifferent operator.

(4) And finally, the keyboard keyer was an attempt to build something no one else ever had, just to have the thrill of knowing you did it.