A home - built, direct printing telegraph system.
***The Feld-Hellschreiber ***

by

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Amateur radio operators have access to many transmission modes. A mode that has generated much interest in the last few years is called Hellschreiber. It allows the user to send text in real time using on-off keying of the transmitter. A recent activity day attracted an estimated 200 operators from all around the world. Free software is available to send and receive Hellschreiber signals using an ordinary PC equipped with a sound card**.** This is the method most people use, as it is easy to set up and operate. Another option is to build, or otherwise acquire, an electromechanical machine based on the original design. This article describes one possible approach to building such a machine.

It is not intended to give a detailed and complete description of the machine, but is presented as a collection of ideas about how such a machine may be constructed from 'junk box' components. No mechanical drawings are presented, however it is hoped that the photographs and description that follow, along with the cited references, will be sufficient for interested readers to build their own machine.

Some History.

Rudolf Hell first developed the original Hellschreiber telegraph system in Germany in 1929. Many pre and post war news services transmitted their bulletins over Hellschreiber circuits, both radio and landline. During World War 2, the German armed forces used Hellschreiber machines extensively. Initial amateur Hellschreiber activity was based on WW2 surplus machines. The system remained in active use until the early 1960's, after which it was supplanted by more conventional Teletype systems, which offered superior performance – albeit with extra complexity. See reference (1) for an interesting and detailed historical survey.

The Hellschreiber messages are not encoded in the same sense as conventional teletype messages, rather each character is sent as a 'bit map' in a 14 by 7 matrix of pixels. As no encoding is done, noise or distortion introduced during transmission cannot change the code from one character to another. The user relies on his or her eyes and brain to sort out the signal from the noise. Such a system is described as 'fuzzy'(1) as it is a mixture of digital and analog processing.

As can be seen from the following example, not all pixels are used. At least two pixels on all four sides of the character are left white to maintain readability, except for characters Q, 3, 5, 6, 7, 9 & ? where the characters extend into the normally white region. Otherwise, each pixel in the matrix can have two states – either black or white – that is, printed or not printed.

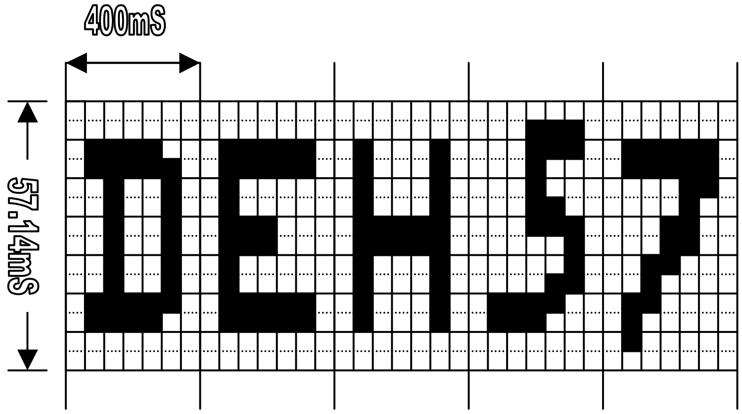


Figure 1: Example character fonts.

The characters are transmitted as a sequence of columns starting at the bottom left hand corner of the above example and working up each column to the right, one column at a time. Note however that single pixels are never transmitted: only groups of two or more are sent. This is done so that the transmitted bandwidth is minimised. Since at least two pixels are always transmitted, the minimum pulse width is 8.16mS, so the maximum Baud rate is 1 / 8.16mS = 122.5

In the original system, reception was accomplished by using a two turn helix rotating at 1050 RPM past a paper tape. The helix was coated with a film of ink applied by an ink pad. A magnet pressed the paper onto the rotating helix every 'mark' pixel. Thus each character was made up of a sequence of lines. There are two main advantages of this system:

(a) Its simplicity.

(b) It performs well in the presence of noise as the eye is very good at (visually) recognizing characters amongst the background of dots caused by any noise pulse.

An important fact to note is that the system does not rely on start or stop bits or special codes to ensure synchronism as in conventional teletype systems. All that is required is that the transmitting and receiving machines are running at approximately the same speed. Of course it is best that the machines at either end of the circuit run as close as possible to the same speed. The effect of speed differences is to make the received text slope one way or the other, it does not cause corruption of the received characters.

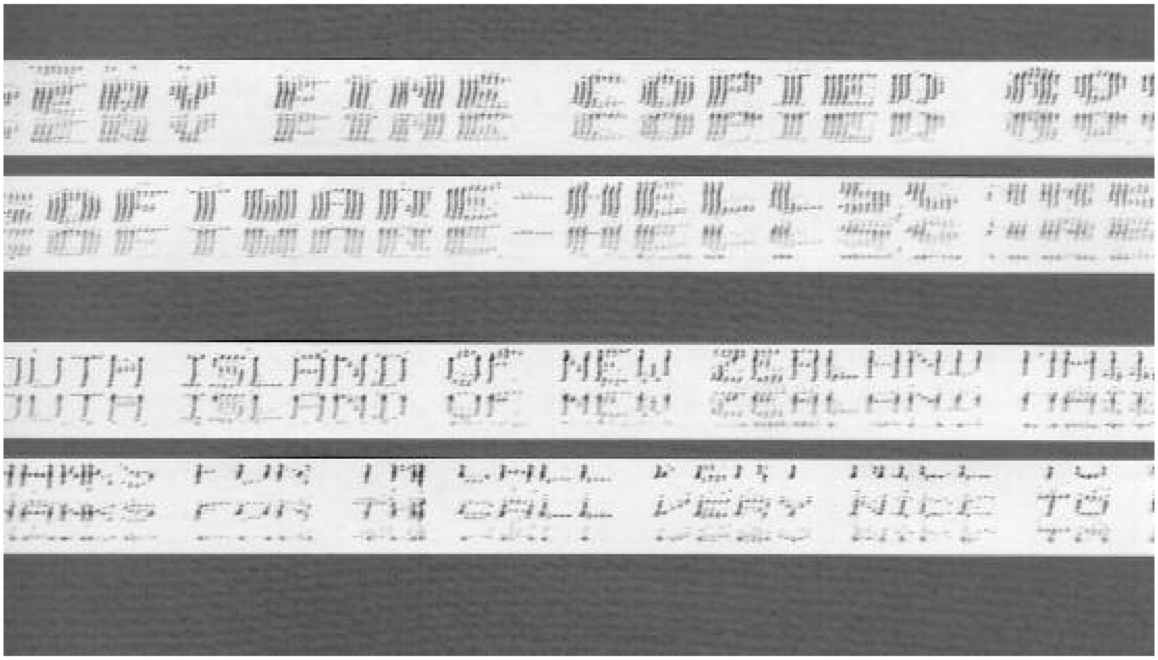


Figure 2: Examples of text printed by the machine, showing double and normal width characters.

As can be seen on the above examples, the text is printed at least twice so that a full line of characters is always visible. This is a function of the receiver alone because the receiver helix has two turns.

The following pages describe the machine that I built based on information found in the various sources cited at the end of this article. In particular I refer people to the excellent web site of Murray Greenman ZP1BPU (ref 1) for historical information as well as links to other sites where software and other data is available.

Figure 3: Home-built Hellschreiber machine.

This machine was built from mostly ‘junk box’ parts. The parts I had determined the end result, so I will only describe the system in general terms (the construction of an identical machine would be most unlikely). For instance, the following parts were on hand:

- the helix drive motor is from a DEC LA120 printer,
- the paper tape feed motor is from a 5.25 inch floppy disc drive,
- the printer magnet is a 3000 type telephone relay,
- an encoded ASCII keyboard from a junked terminal,
- paper tape reel from a junked paper tape punch,
- various other components for the modem and power supply,
- a 65C02 based single board computer system.

The machine consists of three main parts:

(a) The transmitter, which uses a 65C02 microprocessor board to generate the transmitted codes from a stored bit map, reads the keyboard and writes to the display.

(b) The receiver based on a rotating helix and magnet system. The messages are printed onto teletype paper tape.

(c) A modem for radio transmission and reception of the Hellschreiber signals.

The technical details of these systems follow:

The transmitter subsystem.

A 65C02 based single board computer allows the operator to perform the following tasks:

(1) Enter text into memory for later transmission,
(2) Transmit memory contents,
(3) Transmit keyboard characters ‘live’, i.e. as they are typed,
(4) Display contents of the text memory,
(5) Synchronize the CPU to the mechanical operation of the helix @ 17.5Hz
(6) Generate a continuous 980Hz tone to tune the transmitter,
(7) Send automatic CQ sequence,
(8) Display help screens.

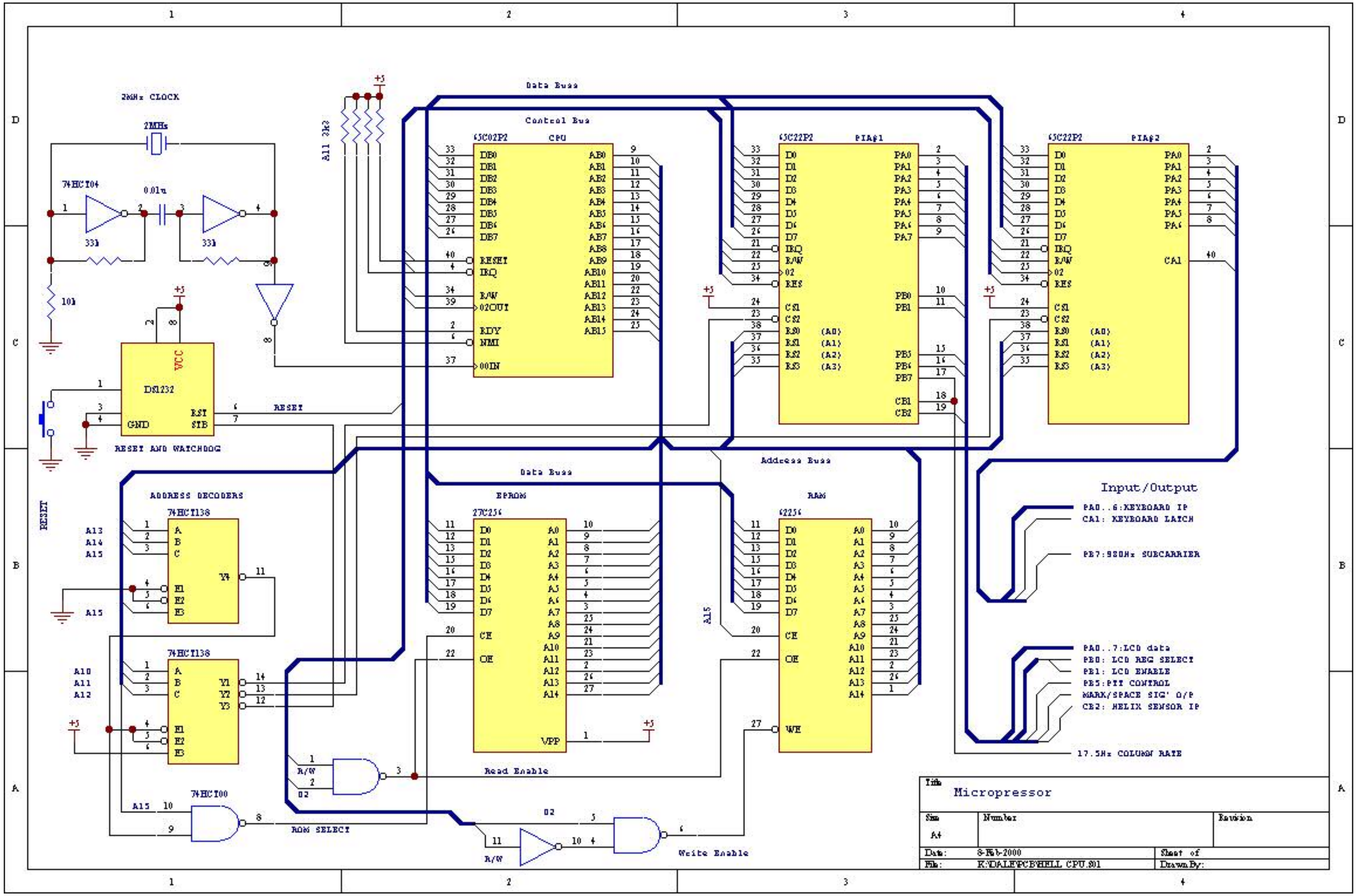
The critical parts of the software are interrupt driven, as this ensures that the timing of the transmitted pulses is always correct. In the ‘live’ transmission mode a type ahead buffer is implemented.

All timing and tone generation is done using the inbuilt hardware timers of a pair of 65C22 chips. These are driven from a 2MHz crystal, so the accuracy and stability of the timing and transmitted tone is high.

The keyboard is an encoded keyboard with a parallel output. This is read via a parallel port of one of the 65C22 chips. Each key press raises an interrupt, and the character is then read into a buffer. Characters are displayed on a 16 character by 2-line liquid crystal display, which is driven by a parallel port from a 65C22. The keyboard is from a junked TTY machine and is over 20 years old!

Characters to be transmitted are generated as a sequence of logic levels, which are then gated with a 980Hz tone. The gated tone is then passed through a filter to produce a suitable sine wave for transmission. See the following modulator circuit for details.

Source code and a printed circuit board layout for the above microprocessor system can be supplied to interested readers.



2MHz CLOCK
2MHz
74HCT04
0.01u
33k
10k
DS1232
VCC
RST
STB
GND
RESET
RESET AND WATCHDOG
All 2k2
Data Buss
Control Bus
65C02P2
CPU
65C22P2
PIA#1
PIA#2
Data Buss
Address Buss
EPROM
27C256
RAM
62256
ADDRESS DECODERS
74HCT138
A13
A14
A15
A10
A11
A12
74HCT00
ROM SELECT
Read Enable
Write Enable
R/W
02
Input/Output
PA0..6:KEYBOARD IP
CA1: KEYBOARD LATCH
PB7:980Hz SUBCARRIER
PA0..7:LCD data
PB0: LCD REG SELECT
PB1: LCD ENABLE
PB5:PTT CONTROL
MARK/SPACE SIG' O/P
CB2: HELIX SENSOR IP
17.5Hz COLUMN RATE
Title
Microprocessor
Size
A4
Number
Revision
Date:
8-Feb-2000
File:
K:\DALE\PCB\HELL CPU.S01
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The receiver subsystem.

The demodulated tones are amplified and filtered to drive a FET which controls the printer magnet. The printer magnet is a modified 3000 type telephone relay. I was initially doubtful whether the magnet would respond fast enough, but it seems to work just fine. However, it takes approximately 1 amp to operate. Each ‘mark’ signal causes the paper tape to be pushed against the rotating helix. The helix has a film of ink applied to it from a piece of sponge rubber soaked with ink. Ink is transferred to the paper tape when contact is made with the helix. The paper tape is advanced for every rotation of the helix, and a photon-coupled interrupter synchronizes the stepper motor so that it does not advance while the line is being written. The paper advance can operate continuously or only when characters are being received. Adjustment of the tension on the paper tape is possible, so that the paper advances consistently. A stepper motor, formerly used to move the heads of 5.25 inch floppy disk drive, actuates the paper advance. The stepper motor is driven by a simple circuit from the ‘Silicon Chip’ magazine of June 1997 (ref 4). Pulse rate and duration is adjustable to give the best paper advance operation.

The spool of paper tape is held on a wheel originally from teleprinter tape punch. Paper passes from the spool to the printer mechanism through a channel just wide enough for the tape, designed to keep the tape correctly aligned with the printer helix.

To ensure that the receiver helix runs at the correct speed of 1050 RPM, a speed control system based on an LM2917 speed control IC is used. The motor I used had an existing shaft encoder at one end, so it was a simple matter to provide a closed loop feedback control. This works very well, and holds the shaft speed to 1050 RPM as required.

The printer helix is a small cylinder of brass, about 25mm in diameter, wound with two turns of 22 gauge steel wire. Dimensions of the helix are not critical, except that its length should be slightly less than the width of the paper tape. Ideally, the wire should be secured in such a way that it does not move.

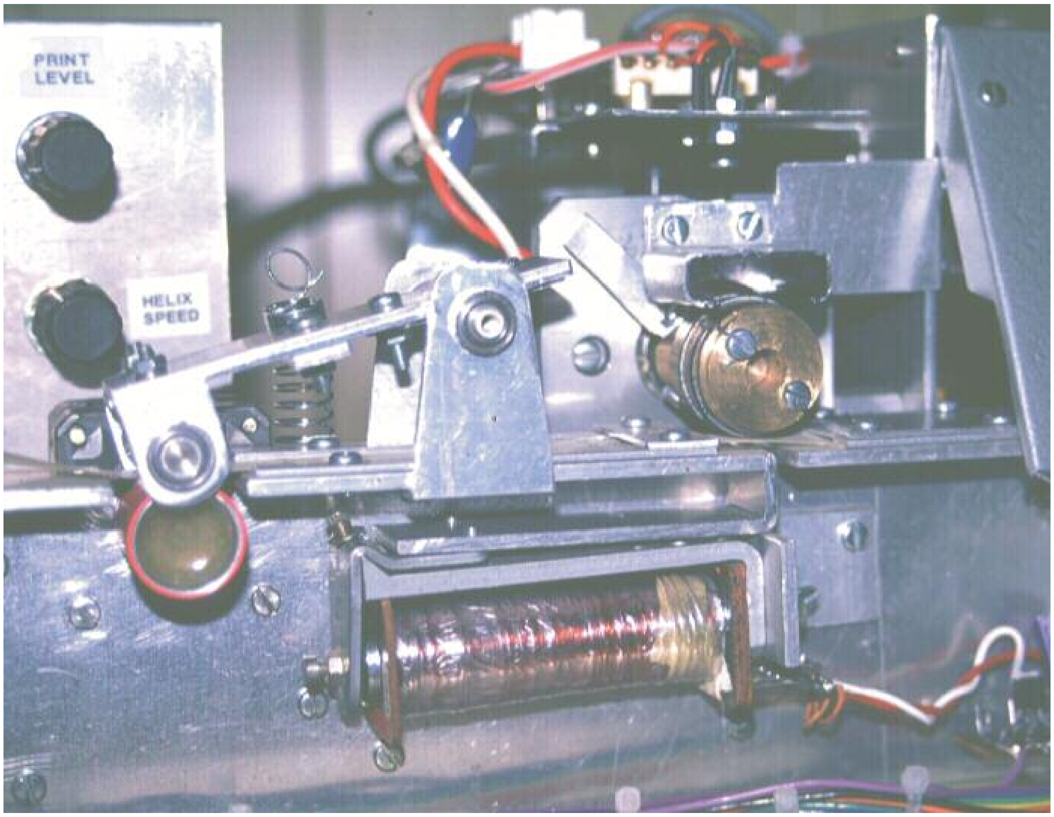

Figure 5: Close up photograph of the printer mechanism showing the printer helix, printer magnet and paper tape advance mechanism.

The modem.

The gated tones generated by the transmitter are passed through a low pass filter then a band pass filter with a Q of 5. The rising and falling edges of the tones are nicely rounded by the filters to minimize transmitted band width. The tone bursts are then amplified by a pair of op-amps forming a push-pull amplifier driving a 600Ω/600Ω transformer. This balanced output then drives the transmitter microphone input through an attenuator so that the transmitter is not overdriven. The attenuator and transceiver interface are located in a separate module. Received tones from the receiver output are coupled to the modem via an input transformer with a selectable input impedance. The tone bursts are amplified and then passed through a two stage band pass filter. Each section of the filter has a Q of 5 and a center frequency of 980Hz. A full wave rectifier, low pass filter and Schmidt trigger produce a voltage to drives the printer magnet. Printer magnet drive can be either from the modem output or from the local keyboard.

No pin numbers or op-amp types are shown on the schematic diagrams as they depend on what parts are used. The unit I built used TL084 devices, but the selection is not critical.

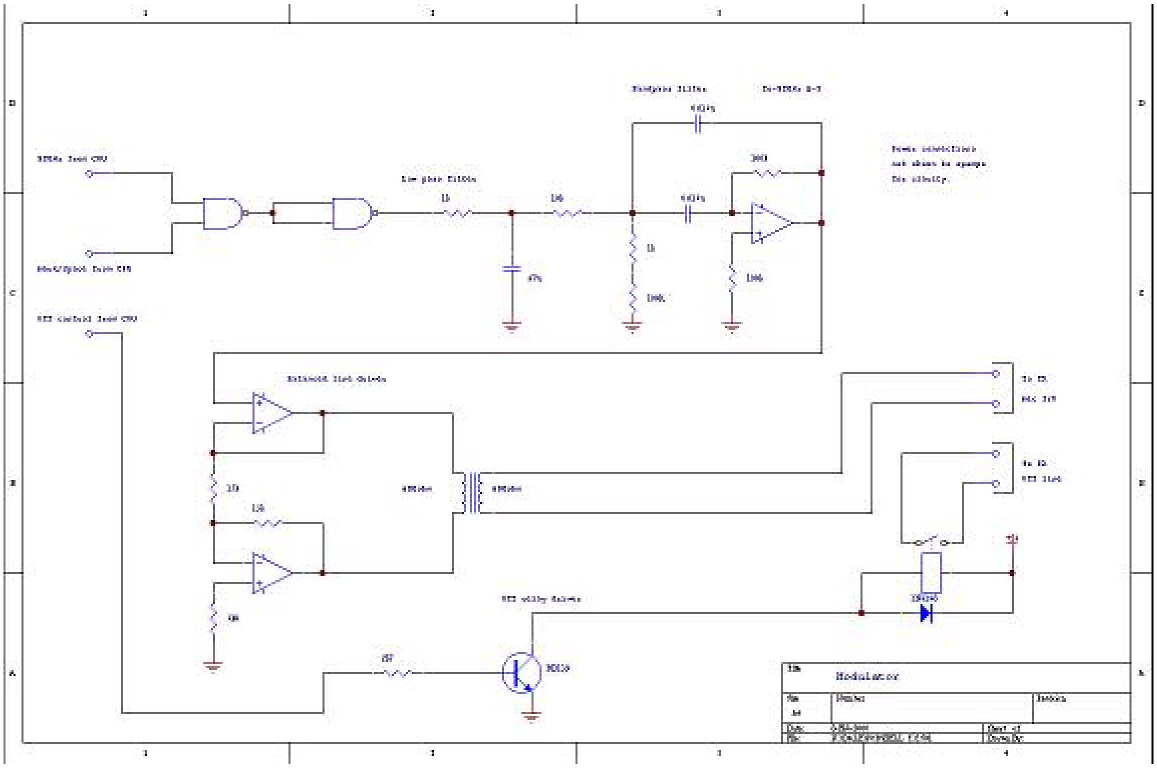

Figure 6: Modulator circuit.

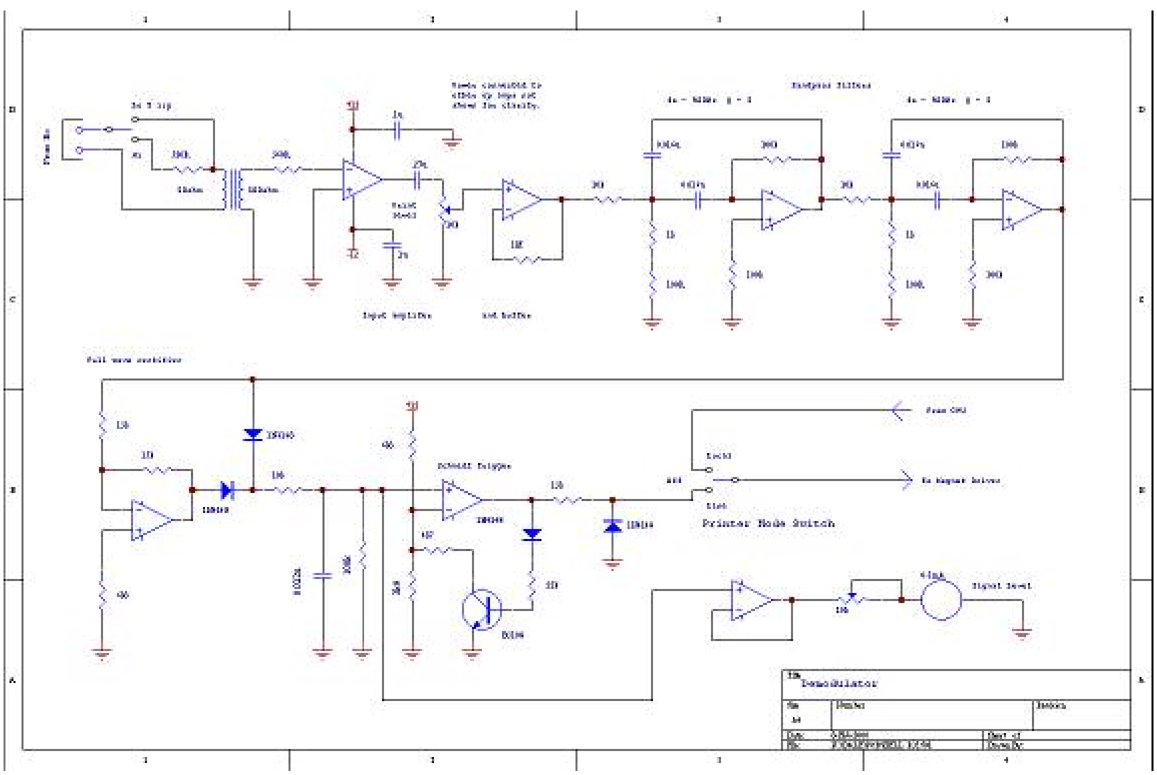

Figure 7: Demodulator circuit.

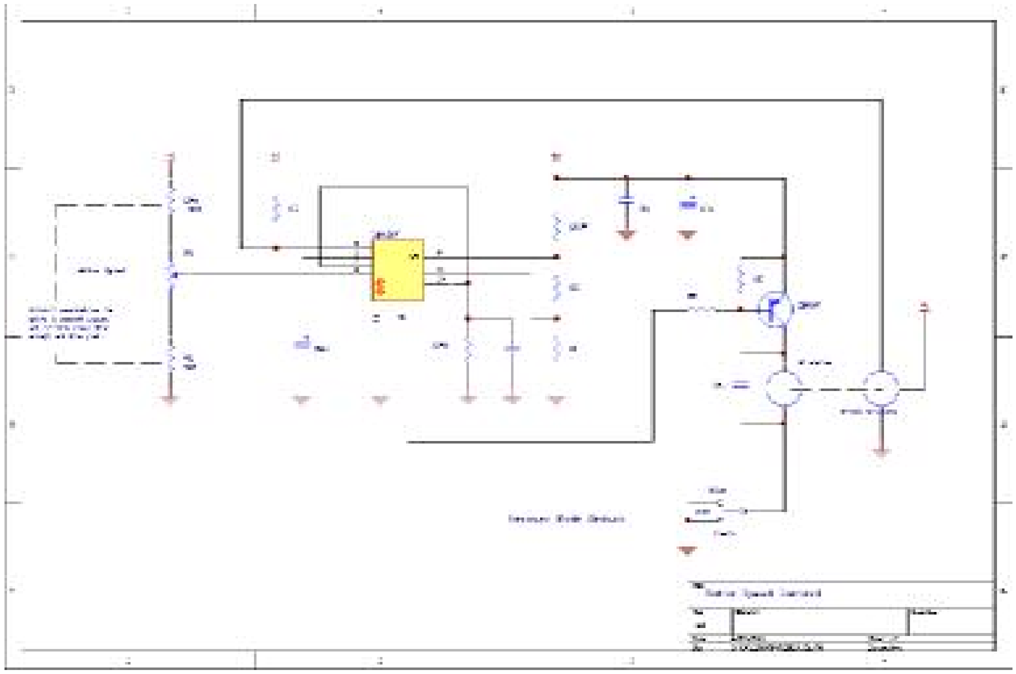

Figure 8: Motor speed control circuit.

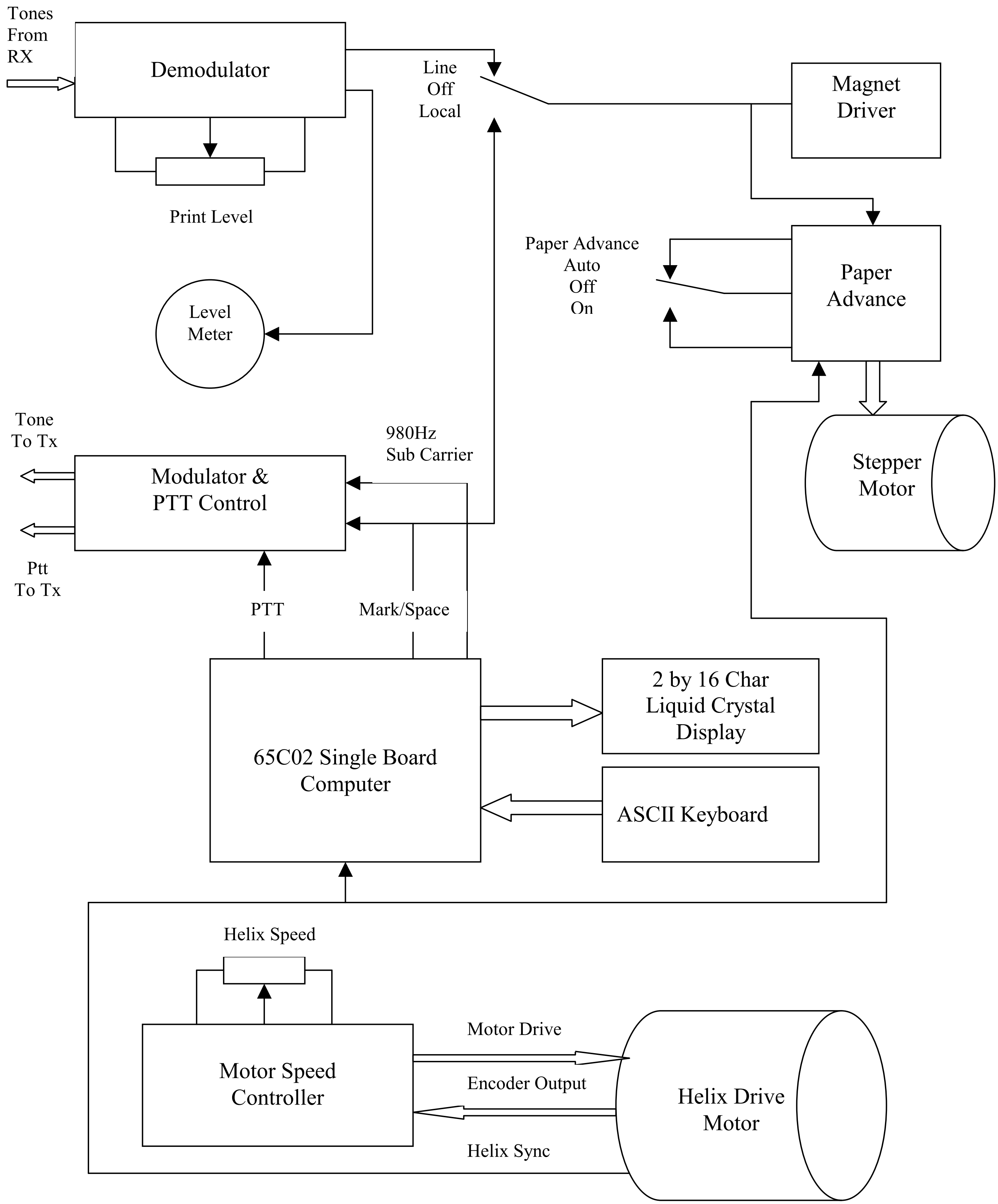

Figure 9: System Block Diagram

Conclusion

I have found the Hellschreiber mode works very well and have enjoyed a number of QSO's. It was a lot of fun to build the machine and to get it to work, and it is very satisfying to use. As I was able to use components from my 'junk box', the cost of constructing the machine was only about AU$50, $10 of which was for a can of suitable spray paint for the front panel!

Two main improvements to the machine could be made:

(a) Use a machined helix instead of the wire and cylinder, this would ensure consistent character height. In the current arrangement, the wire shifts slightly when the printer magnet is actuated, sometimes causing distortion of the printed characters.

(b) The 'live keyboard' mode does not allow editing of typed characters even though they have queued in the transmit buffer. Thus any spelling errors are transmitted….

I hope the ideas presented above will encourage others to have a go at building their own systems or at least use the mode.

Reference Material:

I found the following reference material very useful as a source of ideas and information:

(1) http://www.qsl.net/zl1bpu/FUZZY/Contents.html
(2) Radio Communication, April 1981, Cook, G5XB
(3) Ham Radio, December 1979, Evers, PA0CX
(4) Silicon Chip, June 1997