Automated CW Operation

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Agenda

1.0 Introduction: History and Morse Code Standard

2.0 Morse Code Senders: uC based

2.5 --- Sender Demo ---

3.0 Morse Code Decoders: uC based

3.5 --- Microcontroller Decoder Demo ---

4.0 Morse Code Decoders / Senders : PC applications

4.5 --- Windows Decoder Demo ---

5.0 Future of CW with AI

6.0 Conclusion

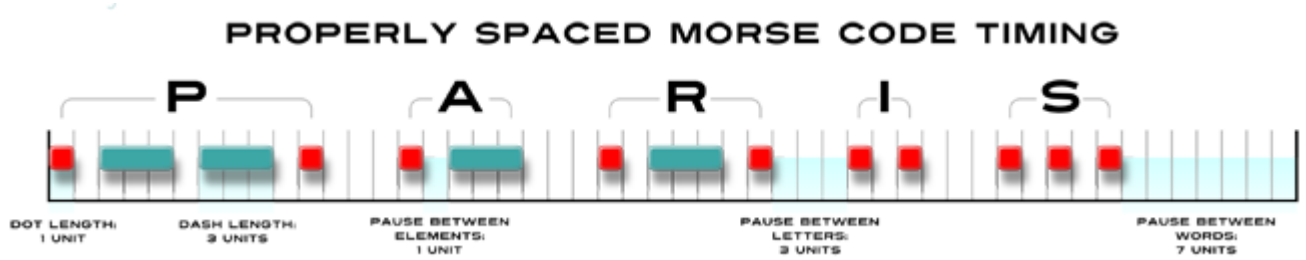
Introduction

- Morse Code is earliest mode of electrical communication
- Uses a sequence of dot and dashes to convey messages
- 1844: Samuel Morse ➔ first telegraph transmission via landline
- 1895: Guglielmo Marconi ➔ first wireless telegraph transmission

Introduction

*Morse code format has the standard following ratios:

- Dash is equal to three dots in lengths
- Spacing between dots and dashes is one dot
- Spacing between letters is three dots
- Spacing between words is seven dots
- No distinction between upper and lower-case letters



WPM is measured by counting “PARIS” instances in one minute.

* PARIS spacing diagram taken from K4ICY website.

Introduction

CW favorite amongst hams:

- Simple transmitters and receivers
- Very effective mode where phone is not useable

Original Morse code reception was done via printer to see dots and dashes
Telegrapher were able to decode it by sound and printers were abandoned

This presentation looks at automation of CW transmission and reception

- Using simple hardware and available software

Automated Morse code decoding is not new.

- Late 1950's: Maude (Morse AUtomatic DEcoder) at MIT Lincoln laboratories.
- 1973: Joel Arthur Guenther: PDP12 Computer decodes human sent Morse code

CW Encoder #1

Morse Code senders are relatively simple devices to build:

Following Morse Code sender was designed by VK2IDL, ID Lindquist

- Arduino circuit powered from USB
- Communication via serial port
- Features LCD to show code being sent
- Adjustable WPM via front panel knob

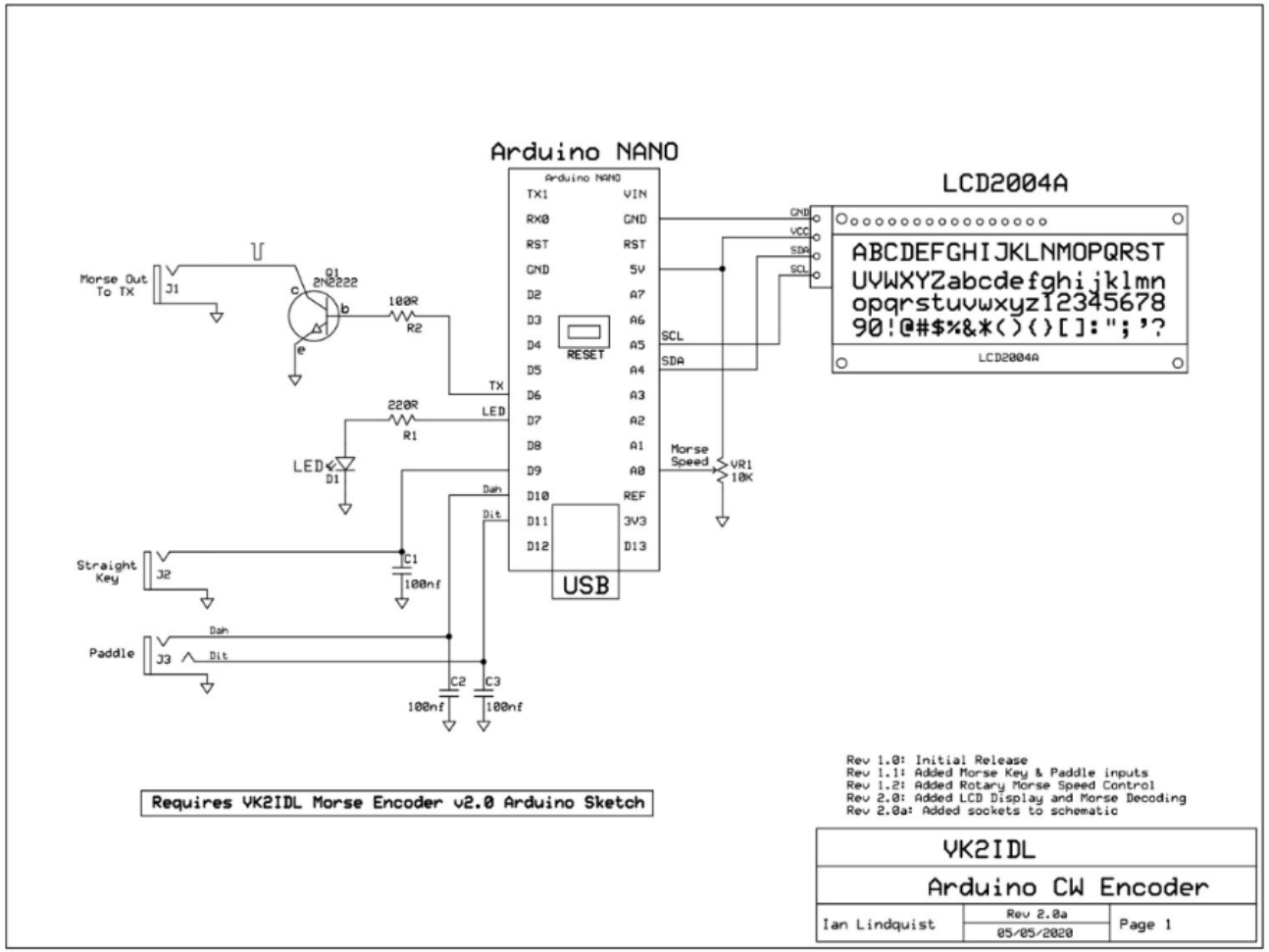
VK2IDL Morse Code Encoder

/dev/ttyUSB0

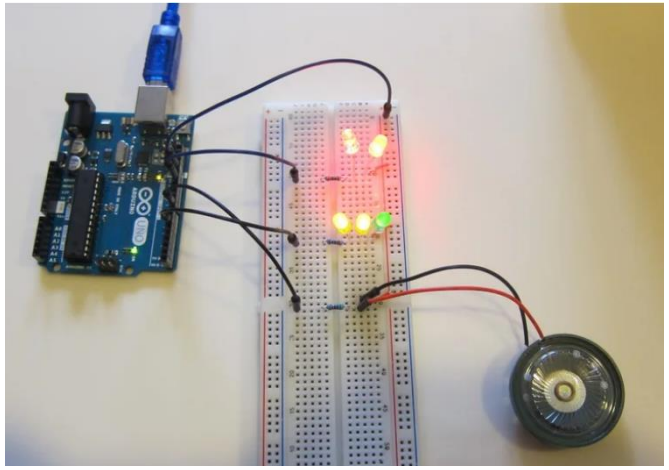
Send

```
=== VK2IDL Morse Code Generator ===

Default morse speed = 12 WPM.
To adjust the Morse Speed (WPM), use the key above the 'Tab' key.
* Press '~' then <Enter> to Increase WPM.
* Press '`' then <Enter> to Decrease WPM.

To select 'Recall' buffers, use the following keys.
[ = Buffer #1       ] = Buffer #2       \ = Buffer #3
{ = Buffer #4       } = Buffer #5       | = Buffer #6


 CQ CQ CQ DE VK2IDL VK2IDL K
```

Autoscroll Show timestamp No line ending 9600 baud Clear output



CW Encoder #2

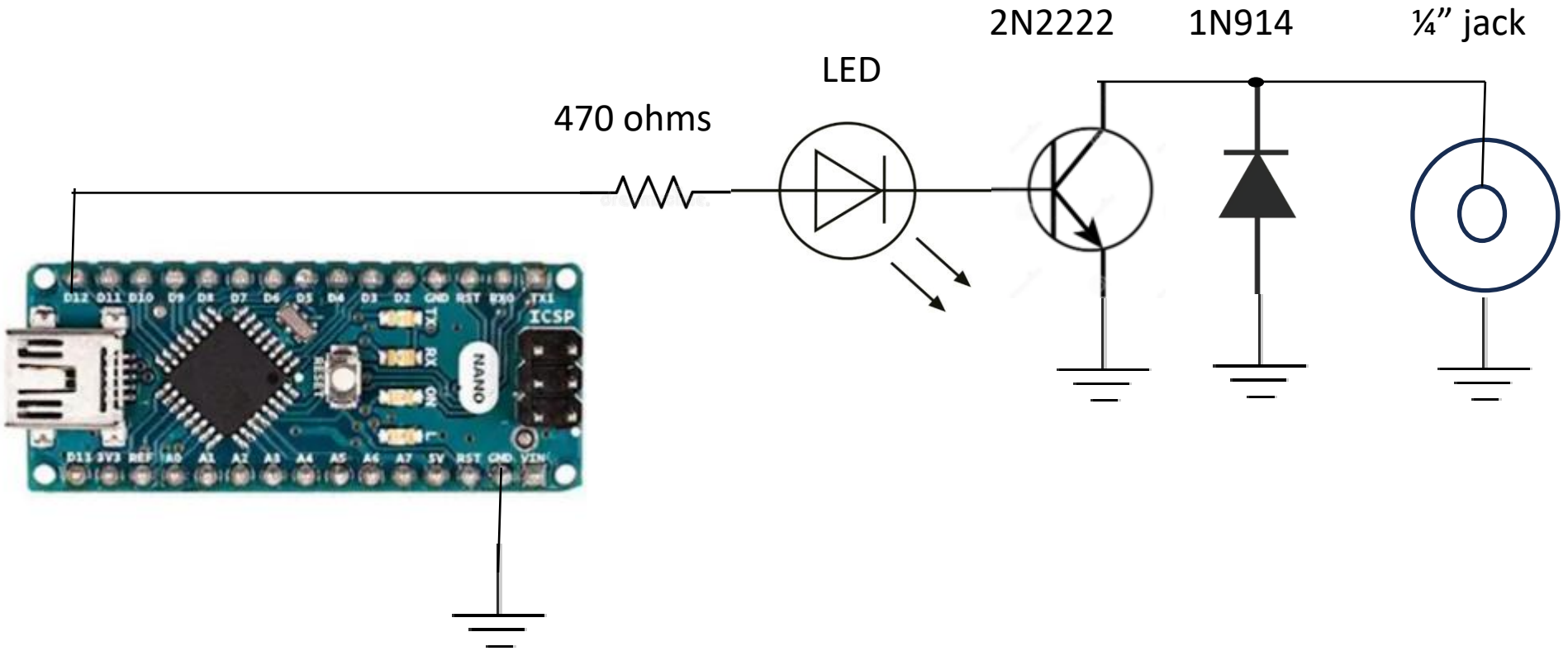


- Based on original code from Chris Weatherford
- His circuit sent hard coded message to speaker & LEDs

VE2GCE modified code accepts user text from serial port and keys transmitter.

- Added ability to change code speed (e.g. *20)
- Option to repeat last transmission (e.g. +)
- Power and serial connection via USB port
- Reduced footprint ➔ Uno to Nano controller

VE2GCE Simple Morse Code Encoder



- Minimalist design (fits in 2 ¼” by 1 ¼” x 1” box)
- User interface via Putty running on Windows

Encoder Demo

Problems with Decoding Morse Code

Building a decoder is more challenging than building an encoder.

Several issues to consider:

1. <u>Decoders require learning period</u>

Assuming perfect code over clear channel. Following steps needed to decode:
a) A series of only dots or dashes can not be decoded right away. Why ?

.. ….. .. … .

➔ Is this message “I5ISE” at 5 WPM ?
➔ or a series of “T” at 15 WPM ?

b) Several mixed symbols are received ➔ dot / dash relative sizes are measured
c) Thresholds calculated ➔ Actual decoding and speed measurement takes place.

Problems with Decoding Morse Code

2. Imperfect RF channel

a) Maximize Signal to Noise ➔ Manual setting (volume) or decoder AGC

b) Tone Lock with Noise + Crosstalk present➔ HW PLL or HW / SW filter

3. Human sent code (imperfect)

a) Dash / Dot ratio variations ➔ Decoder algorithm

b) Jitter and variations in speed ➔ Decoder algorithm

VE2AO Decoder #1

Loftur E. Jonasson VE2AO/ TF3LJ Morse Code Decoder

Uses OZ1JHM “Goertzel” filter + work by Joel Arthur Guenther

1) Uses Hjalmar Hansen OZ1JHM implementation of Goertzel Algorithm

- Goertzel Algorithm does Audio Tone Processing (i.e. single tone detector)

Goertzel filter detects presence or absence of tone in noisy environments

2) Jitter and non-uniform speed of human sending is a big problem

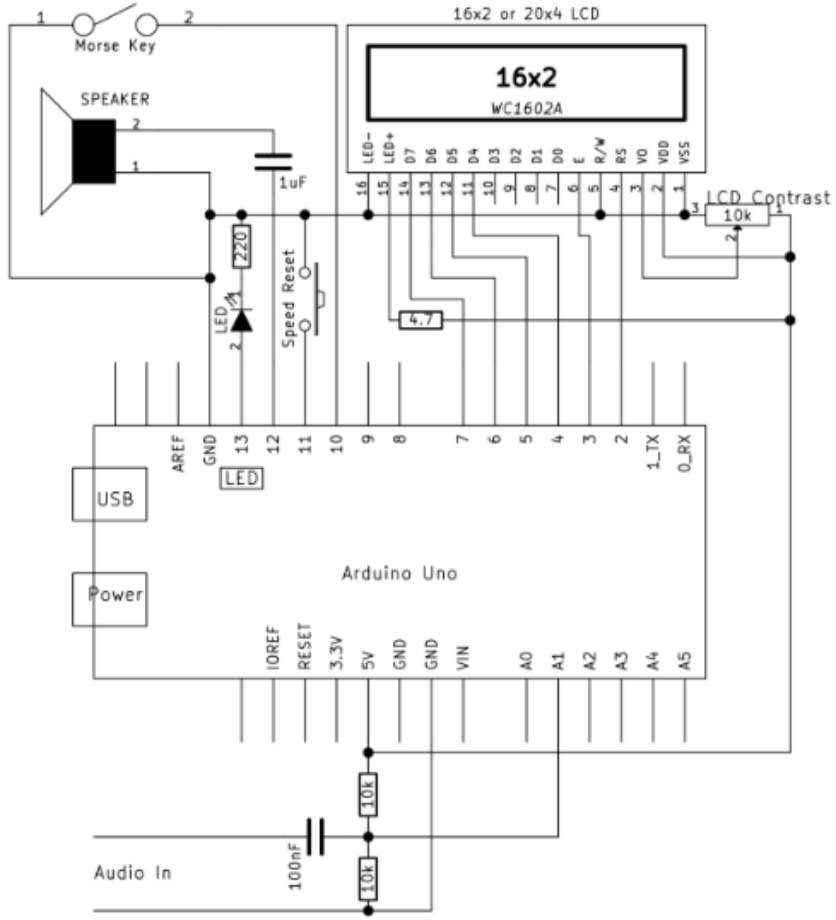
Guenther algorithm addresses imperfectly human sent Morse code

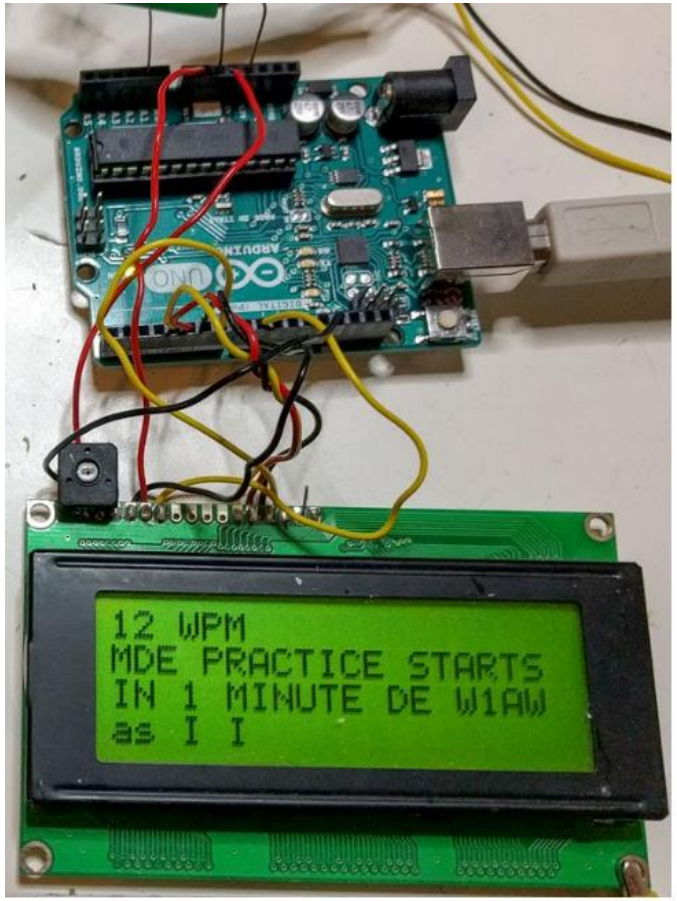
- Bayesian distribution/classification algorithm to classify ambiguous signals

Example: Tone’s duration is measure at 100 ms.

- Based on past data, dots are usually 80-150 ms and dashes 200-350 ms.
- Dots more frequent than dashes. e.g. 599 often sent as 5NN to save time.

VE2AO Decoder #1





- Set amplitude (volume) and frequency (tune) until lock LED flashing corresponds to audio in speaker.
- Much improved performance over RF channel than Goertzel filtering alone.
- Requires buffering 20 characters in learning mode. Initial characters are not lost, only delayed.

VE2AO Decoder #2

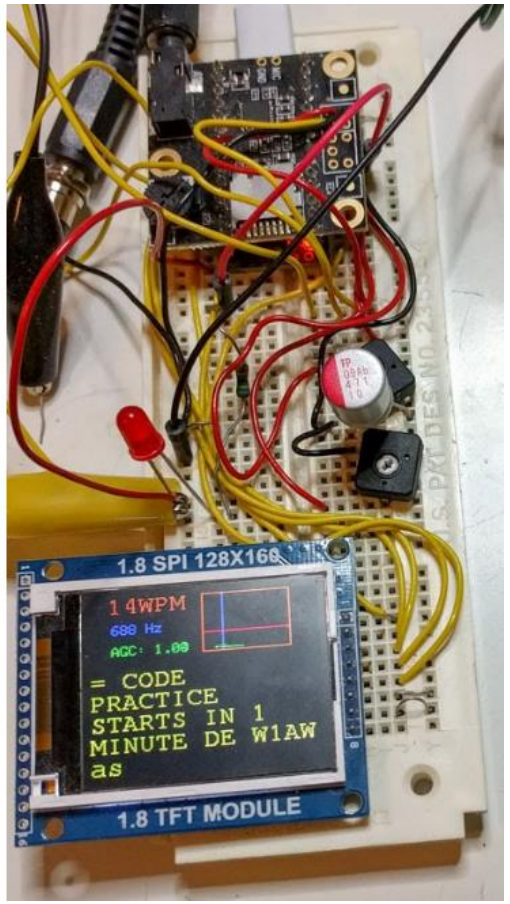
Loftur E. Jonasson VE2AO/ TF3LJ Morse Code Decoder (Teensy)

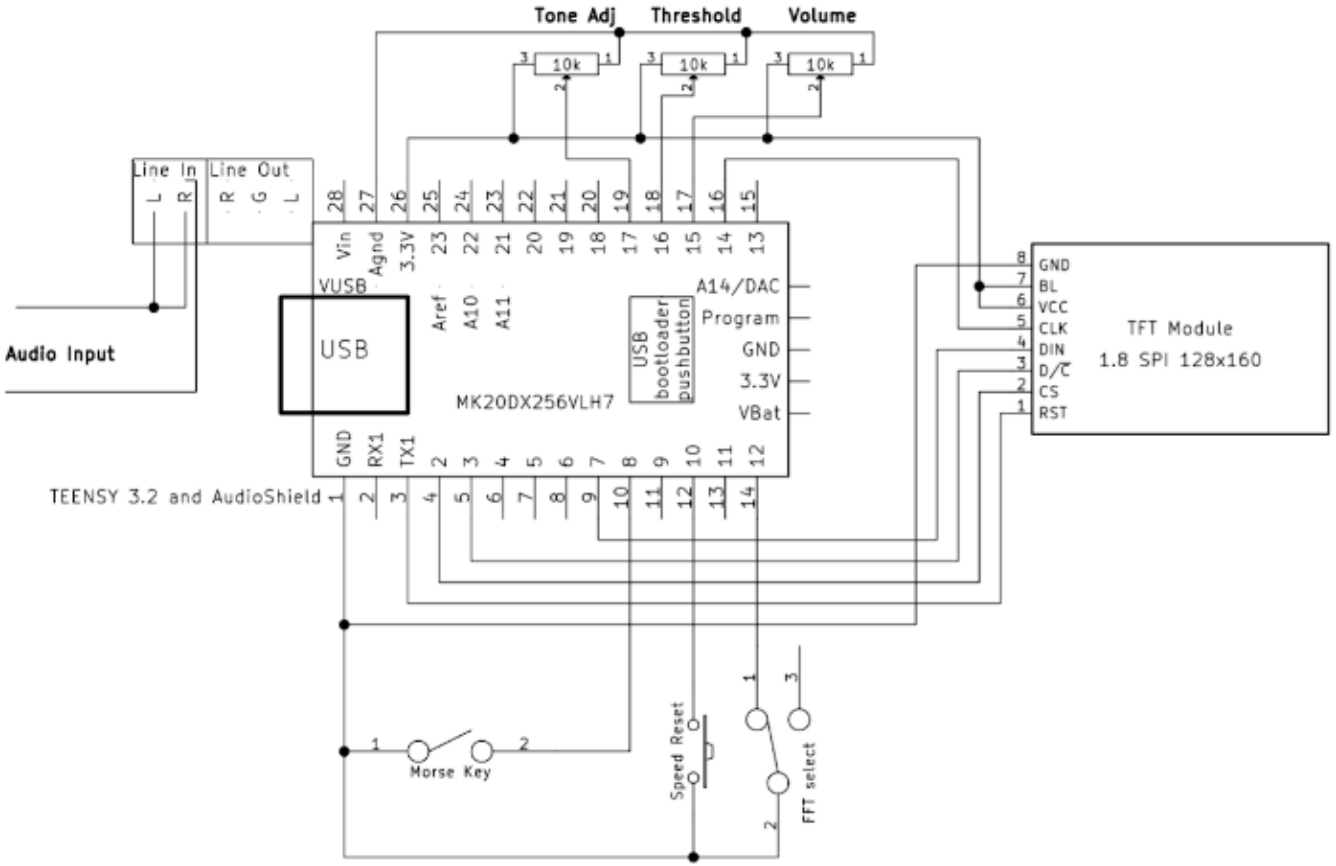
Loftur other decoder design uses Teensy 3.2, more powerful than Arduino Uno

➔ Uses Joel Arthur Guenther algorithm with FFT in lieu of Goertzel Algorithm

This permits more processing and features

- TFT color LCD for Waterfall-type display
- Teensy Audio Shield: A/D conversion for precise audio analysis
- FFT256 or FFT1024 capability to filter the multi-tones (not possible with Arduino)
- Additional noise cancelling methods further clean up the signal before decoding





Via visual queues, one can adjust using three trimpot resistors

- Volume (Signal Strength)
- Signal level threshold (ON / OFF decision point)
- Peak tone frequency of the desired signal (no need to tune receiver)

Excllent decoding performance over RF channel

WB7FHC Decoder

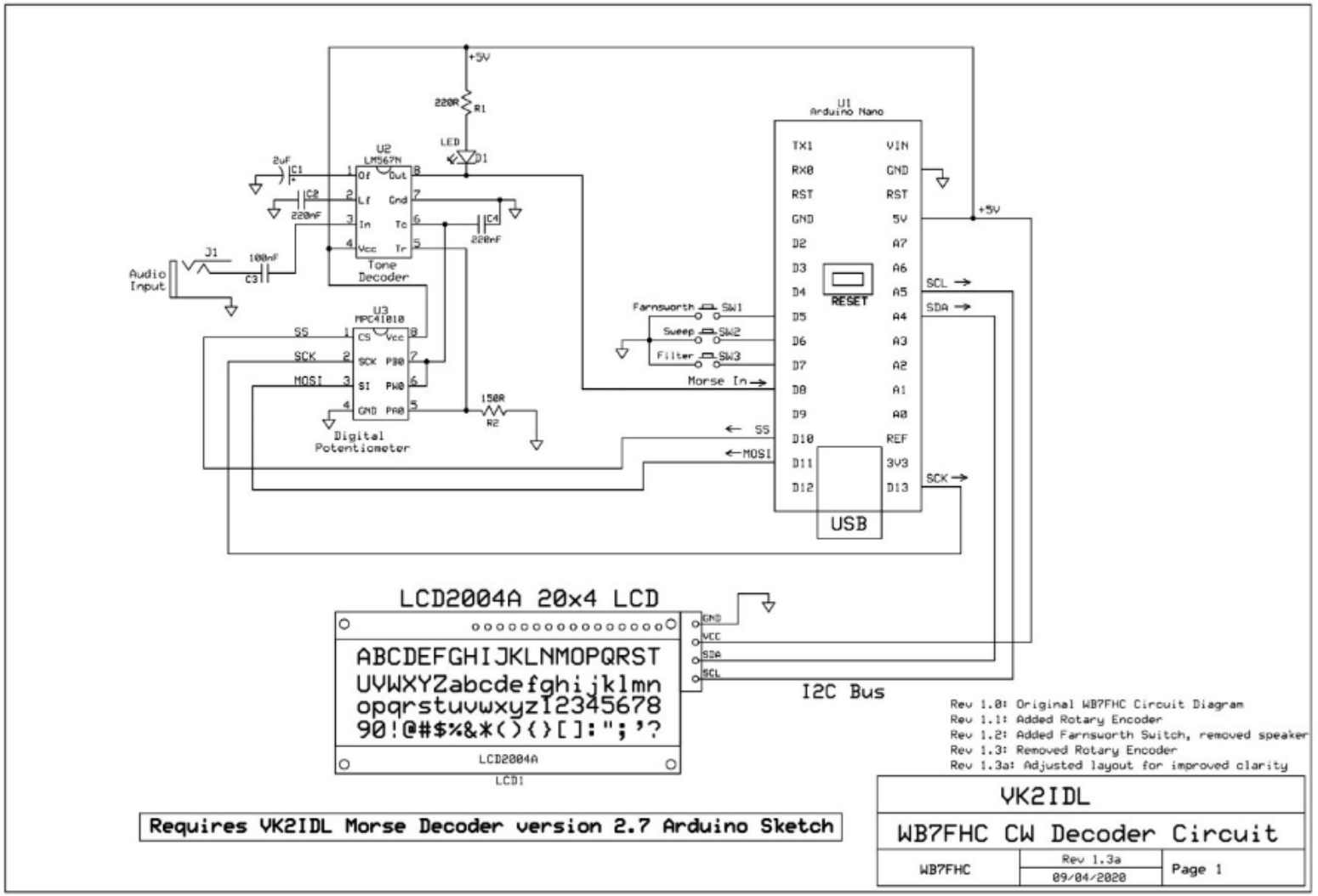
Budd Churchward, WB7FHC Morse Code Decoder

Churchward presents an interesting approach

He uses additional *HW compared to previously designs

1. Conventional Arduino controller and 2004 LCD display
2. *LM567 tone decoder
3. *MPC41010 Programmable Resistor array to tune LM567 frequency on the fly
4. Software filtering
5. Farnworth option to override standard Morse code spacing requirement.

Farnsworth method for morse training sends characters at a higher speed (say 15 wpm) while maintaining spacing at a lower rate say 5 or 8 wpm
This method permits faster learning of Morse code



- I built VK2IDL version of the WB7FHC circuit.
- Excellent performance over RF channel
- The autotuning PLL feature is very nice.

K4ICY Decoder

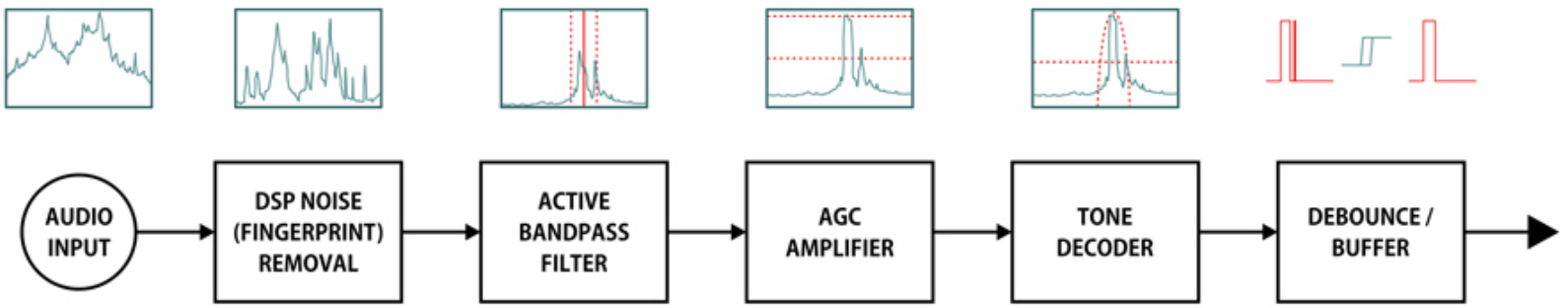
Michael A. Maynard K4ICY Morse Code Decoder

Michael presents interesting approach, different than other methods

He uses even more *HW compared to previously approaches

1. Conventional Arduino controller and 2004 LCD display
2. *Selectable 1, 2 or 4 stages of two pole OPAMPs bandpass filters
3. *LM567 tone decoder (like WB7FHC)

Use geometric decision threshold instead of arithmetic threshold

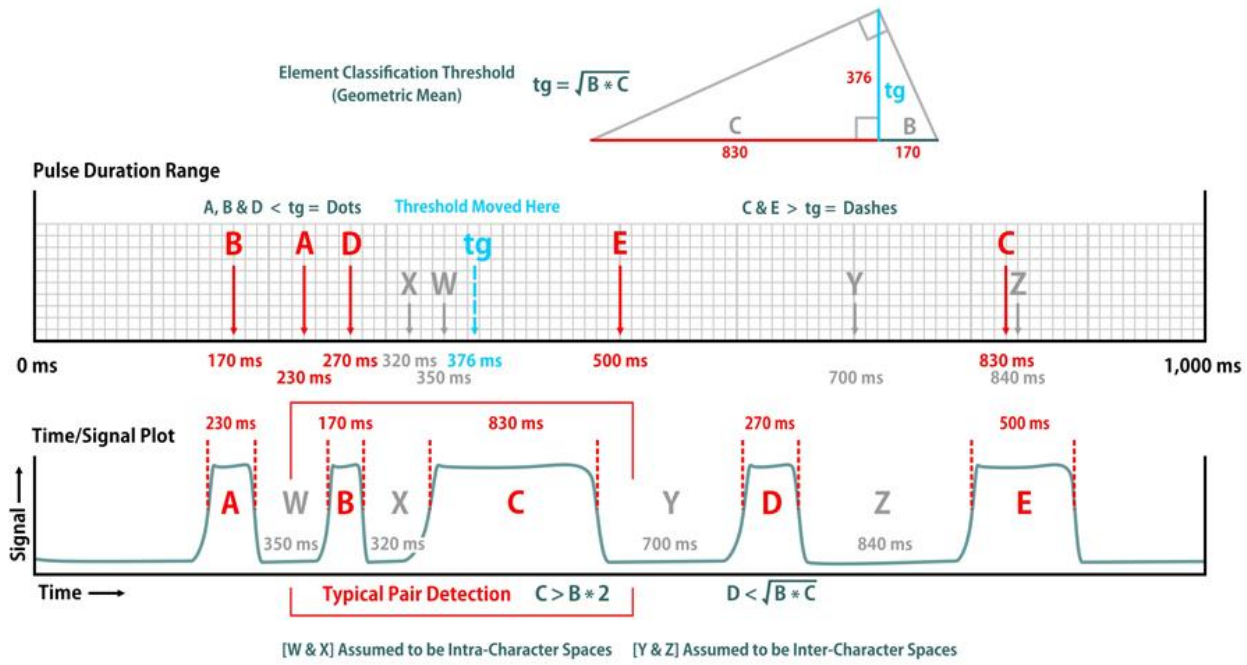


CW Decoder - Suggested Audio Input Signal Pre-Conditioning

K4ICY Decoder

Decision threshold calculation is quite novel.

Dash lengths ➔ more variable than dot lengths



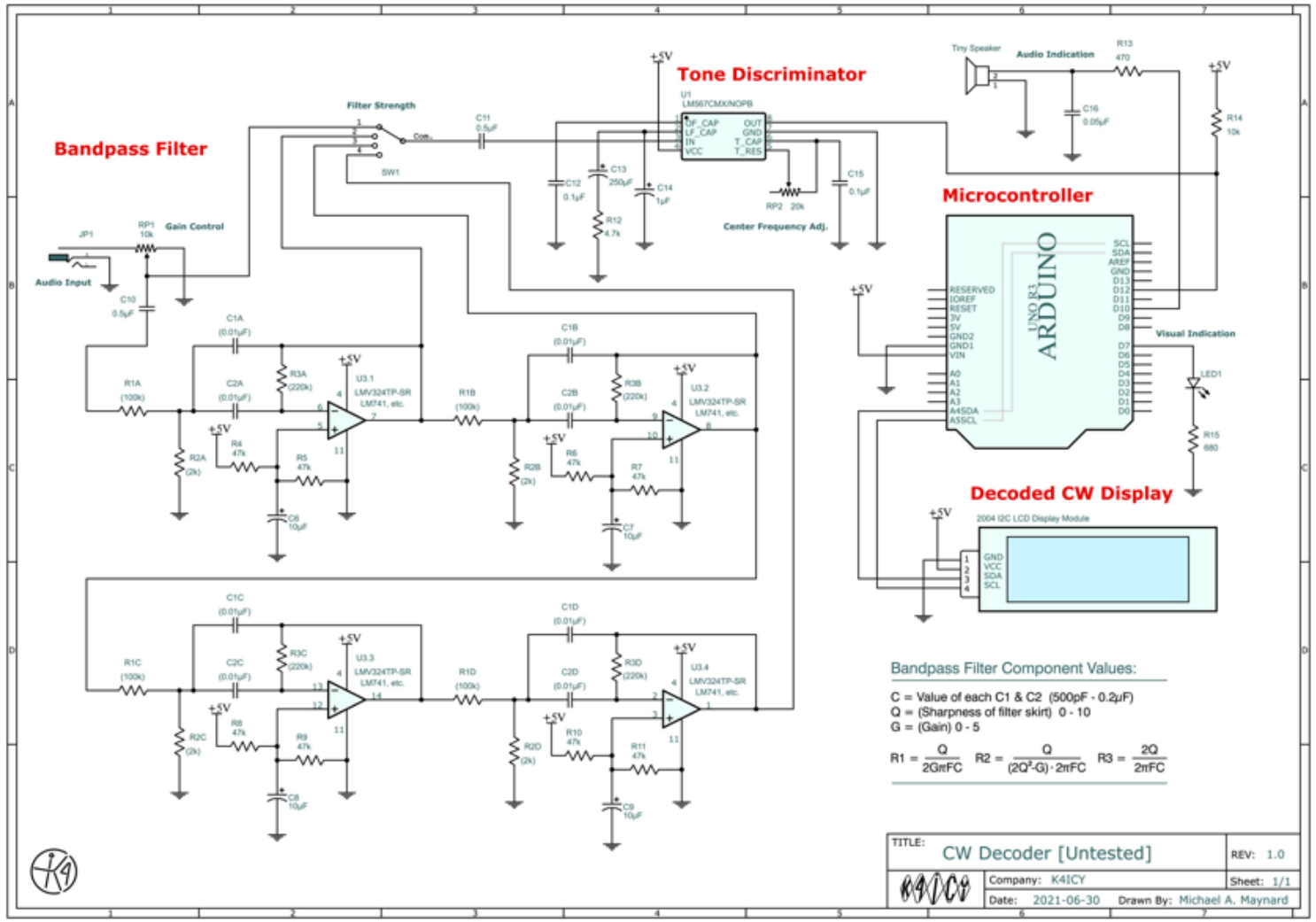
Visual Example of The K4ICY CW Decoder Morse Code Element Classification

<u>Arithmetic approach</u>

1. Take smallest dot and largest dash. (170 mS and 830 mS)
2. Calculate arithmetic average; 500 mS becomes threshold
3. Symbol E (500 mS) sits on decision threshold, can be decoded either way.
   ➔ Dot or dash ?

<u>Geometric approach</u>

1. Take smallest dot and largest dash. (170 mS and 830 mS)
2. Calculate geometric average; 376mS becomes threshold
3. Symbol E (500 mS) is in stable region and be decoded without confusion.

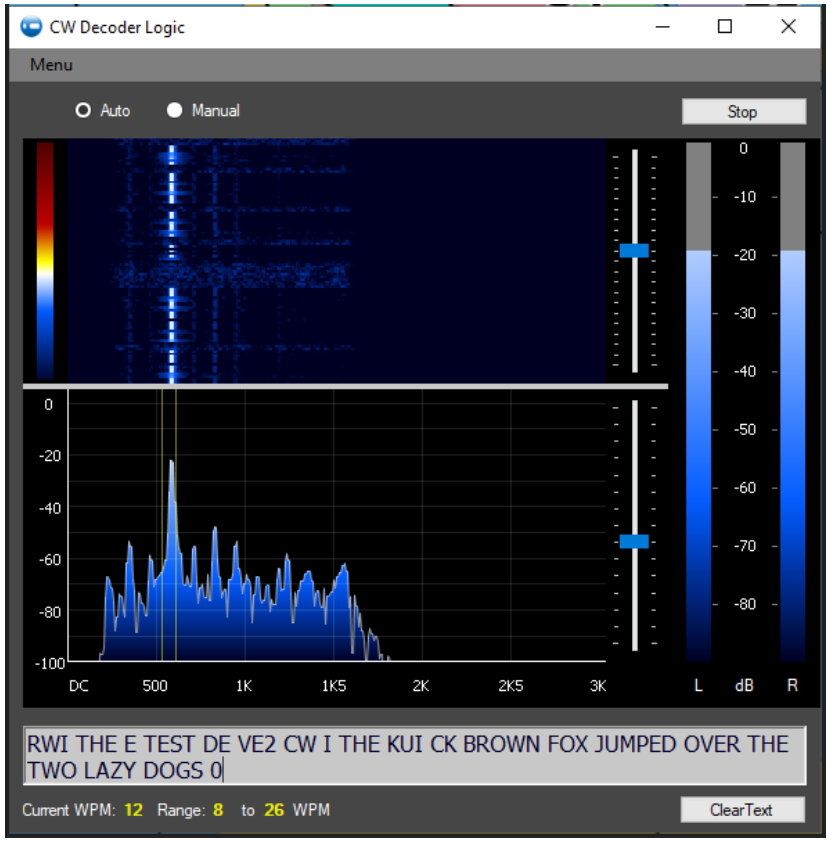


- I have not built and tested the K4ICY circuit yet
- Involves tuning each Bandpass stage (OPAMP) and manual tune of PLL
- Expected performance ➔ like WB7FHC or better

Decoder Demo #1

CW Decoder Logic

CW Decoder Logic by Žilvinas Batisa LY3H



Pros:

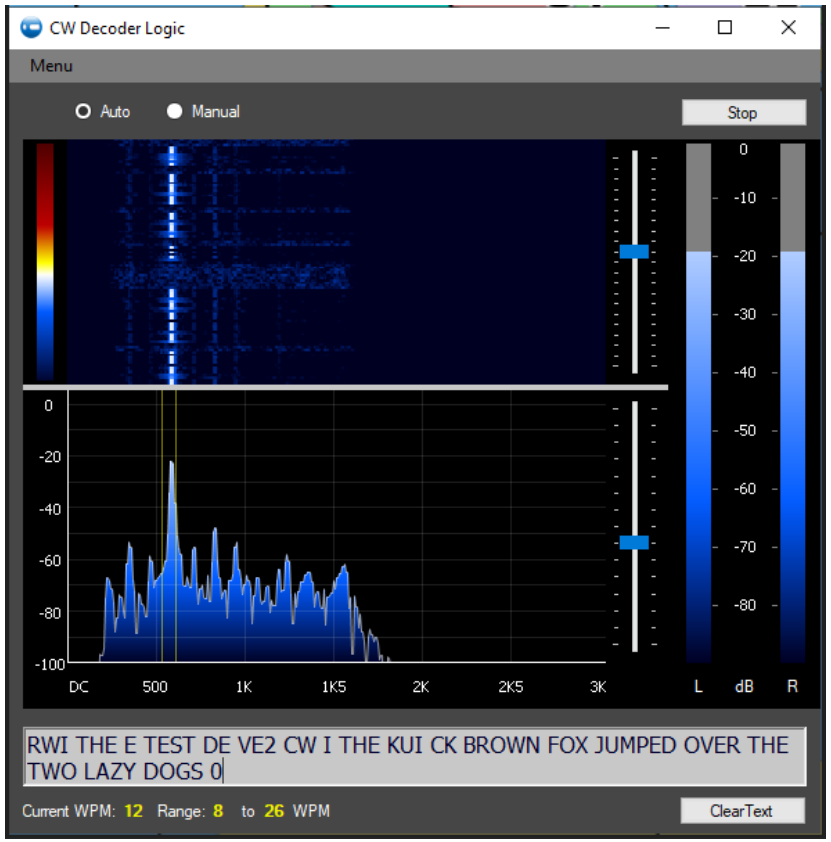
- Free
- Simple to configure and to use
- User friendly display
- Features: Auto Threshold, AFC, auto/manual mode
- Logging support

Cons:

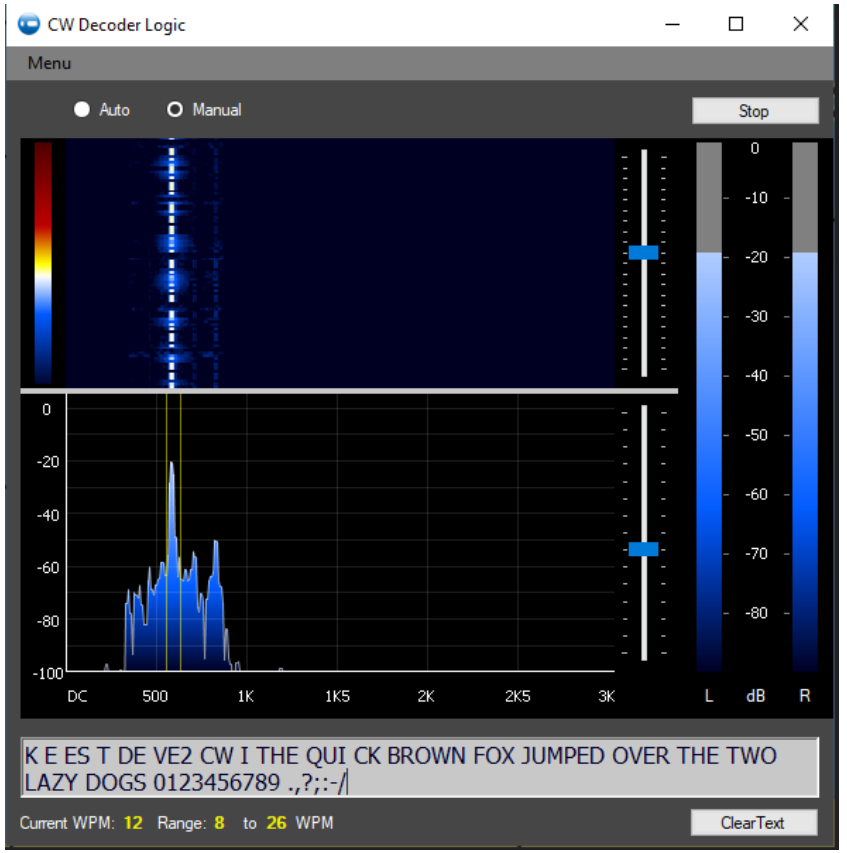
- Poor decode on weaker signal
- Minimal documentation

Icom 7300 Filtering Settings

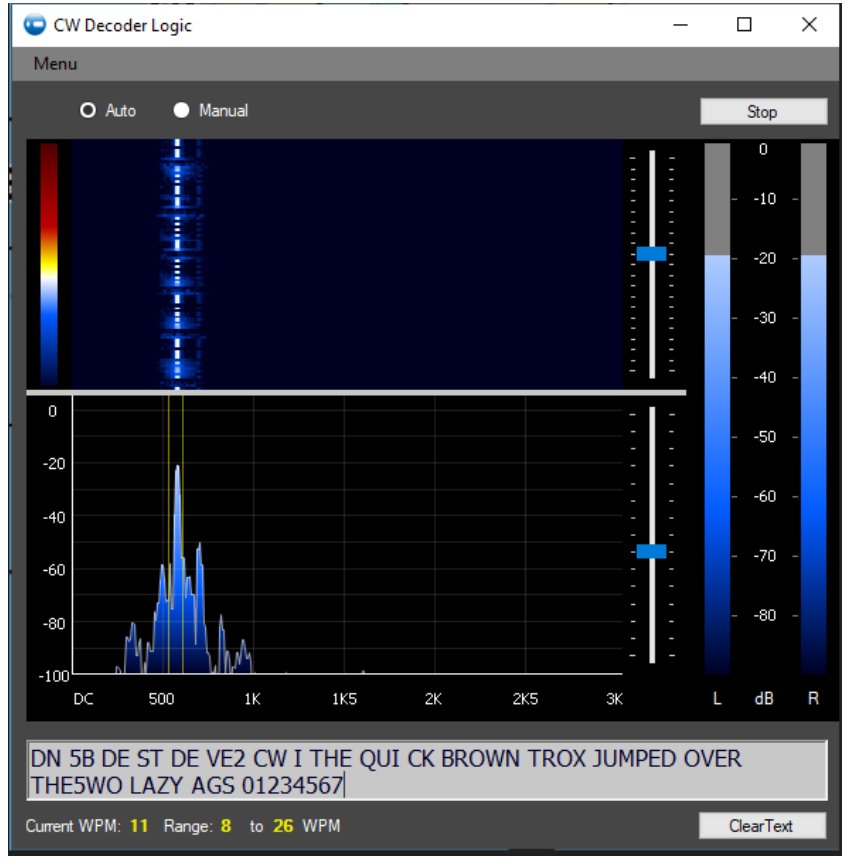
Bandwidth window shown below for different Icom 7300 filter settings



Filter #1: BW =1200 Hz



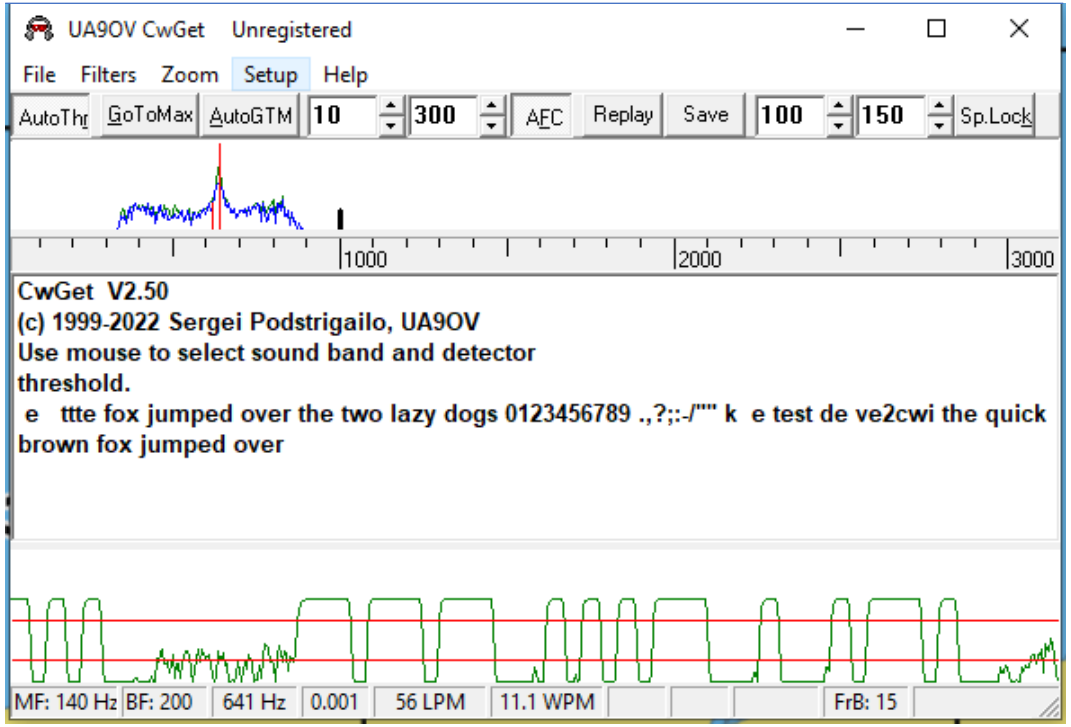
Filter #2 (Default): BW =750Hz



Filter #3: BW =400 Hz

CW Get

CW Get by Sergei Podstrigailo, UA9OV



Pros:

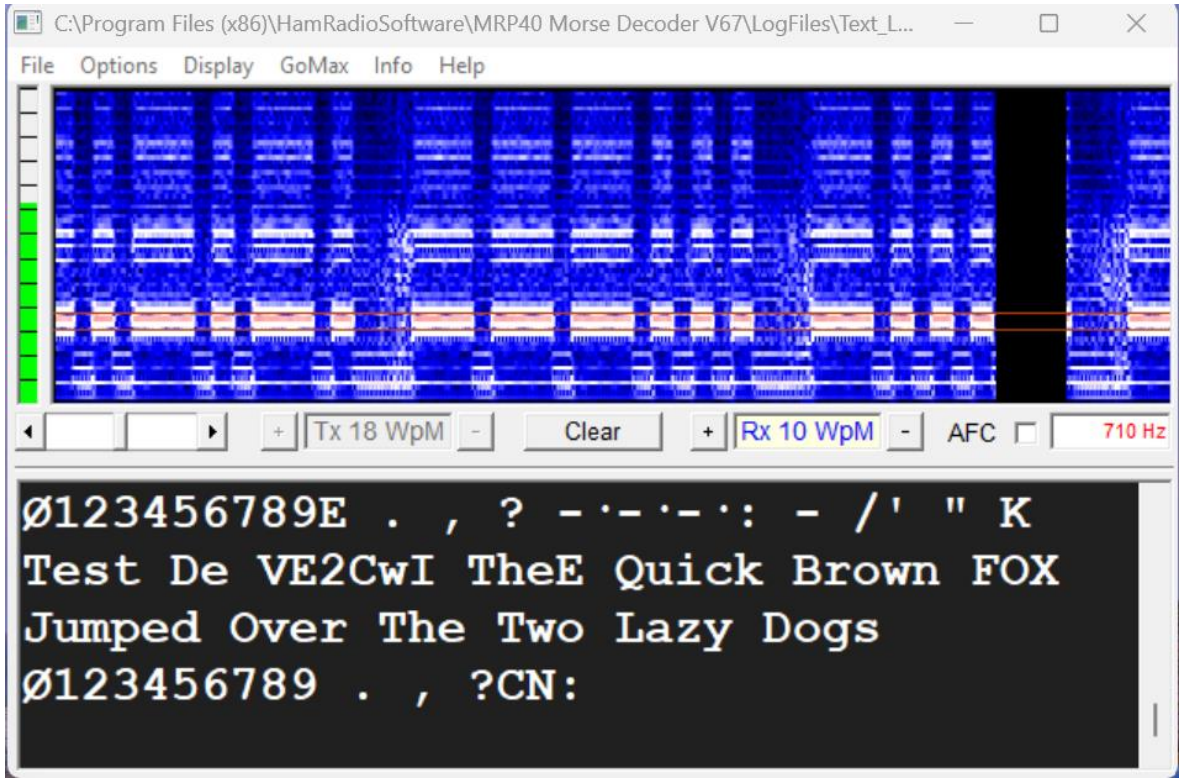
- Free (reasonable registration $35 if you like it)
- Simple to use
- Nice spectral and live code stream display
- Features: Auto Threshold, Go to Max, AFC
- **Cw Type** for sending code

Cons:

- Moderate weak signal de-code
- Minimal documentation

MRP40

MRP40 by Norbert Peiper



Pros:

- Simple to use
- Excellent weak signal de-code
- Nice visual representation of received code
- Well Documented
- TX capability
- Logging support
- Many features, too numerous to list here

Cons:

- Expensive 60€ ($96 Cdn) to unlock beyond 30 day trial
- Horrible SW download experience ➔ always flagged as malware when downloaded

  Author's solution ➔ disable your Malware scanner (???). Not a very reassuring solution.

Decoder Demo #2

Conclusion

1. Encoding Morse Code is very easy to do (e.g VK2IDL and VE2GCE)

2. Decoding Morse is very challenging.
   Many clever approaches were examined to address multiple problems over the RF channel

Decoder	Tone Lock	Signal Level	Filtering	Dot/Dash Threshold	Additional Features	Maximum Performance
VE2AO – Arduino	Manual Tune	Manual Set	Goertzel	Bayesian		30 WPM
VE2AO - Teensy	Manual Tune	Manual Set	FFT 256 /1024	Bayesian		40 /20 WPM
WB7FHC	Auto HW PLL	Manual Set	8 x level SW	Arithmetic	Farnsworth	25 WPM
K4ICY	Manual HW PLL	Manual Set	4 x Active BPF	Geometric		Not Tested
LY3H - CW Decoder Logic	Automatic	Automatic	DSP	DSP		60 WPM
UA9OV - CW Get	Automatic	Automatic	DSP	DSP	TX sender	60 WPM
MRP40 - Norbert Pieper	Automatic	Automatic	DSP	DSP	TX sender	60 WPM

Near Future

What's next ? **Machine learning**

After training with relevant data, machine learning can do the following:

1. **Recognition:** Differentiate between two entity types (e.g. dog versus cat)
2. **Prediction:** Predict future events based on current and past events.
   (e.g. Estimate mortgage rates in one year or predict election results)

Amateur transmission of Morse Code is far from perfect.

Recognition at Micro level: dot vs dash, individual characters, words (correct misspellings)

Prediction at Macro level: Many amateur radio transmissions are deterministic:

- Contesting: Exchange of call signs, signal reports, grid squares, contest identifier (e.g. FD)
- Rag chewing: Exchange of call signs, names, signal reports, location, weather, equipment, etc.

Machine learning should make automated Morse Code decoding perfect.

➔ The Future: No dedicated HW, cloud-based processing, automated CW contesting

References:

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Morse_Arduino_V5.7z

4. Loftur E. Jonasson, VE2AO/ TF3LJ Morse Code Decoders *https://sites.google.com/site/lofturj/14-machine-recognition-of-hand-sent-morse-code*
5. Hjalmar Skovholm Hansen, OZ1JHM Morse Code Decoder *http://www.oz1jhm.dk/content/very-simpel-cw-decoder-easy-build*
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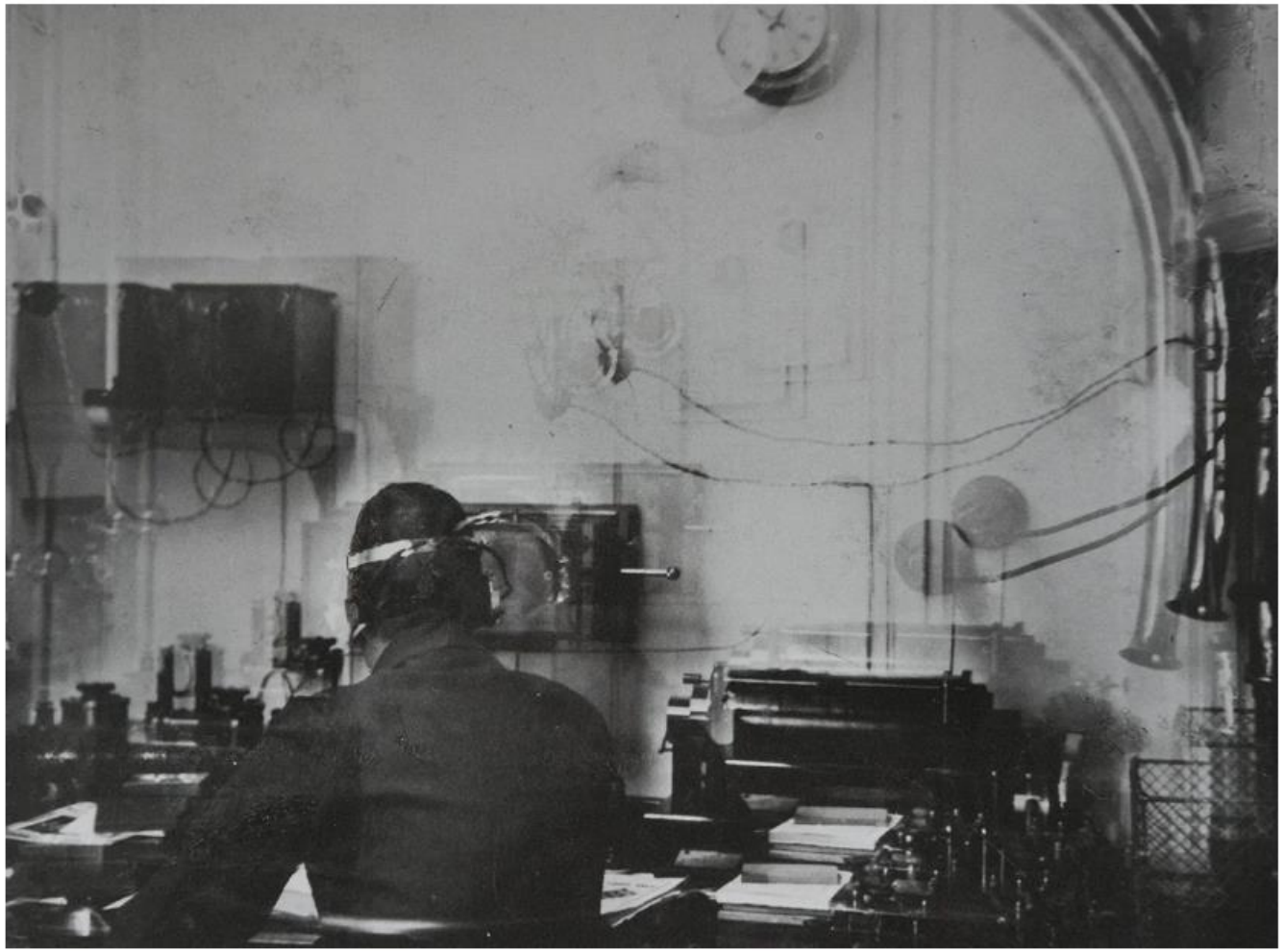
7. Towards Bayesian Morse Decoder Mauri Niininen AG1LE https://ag1le.blogspot.com/2013/01/towards-bayesian-morse-decoder.html
8. Budd Churchward, WB7FHC Morse Code Decoder https://wb7fhc.com/m2-cw-decoder.html
9. VK2IDL version of WB7FHC Morse Code Decoder https://vk2idl.com/index.php/morse-code-decoder/
10. Michael A. Maynard, K4ICY https://www.k4icy.com/cw_decoder.html
11. Žilvinas Batisa LY3H CW Decoder Logic *https://cw-decoder-logic.software.informer.com/download/*
12. UA9OV CW Get https://www.dxsoft.com/en/products/cwget/
13. UA9OV CW Get and CW Type https://www.qsl.net/wm2u/cw.html
14. MRP40 Morse Decoder and Sender https://www.polar-electric.com/Morse/MRP40-EN/

Questions ?



Only known photograph of Titanic radio room: 1912 Father Francis Browne