

# A Radio Relay System for Remote Sensors in the Antarctic

## Final Seminar

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# Motivation

**Aim** - Design and build a low power HF data transmitter for use in an antarctic remote sensor application.

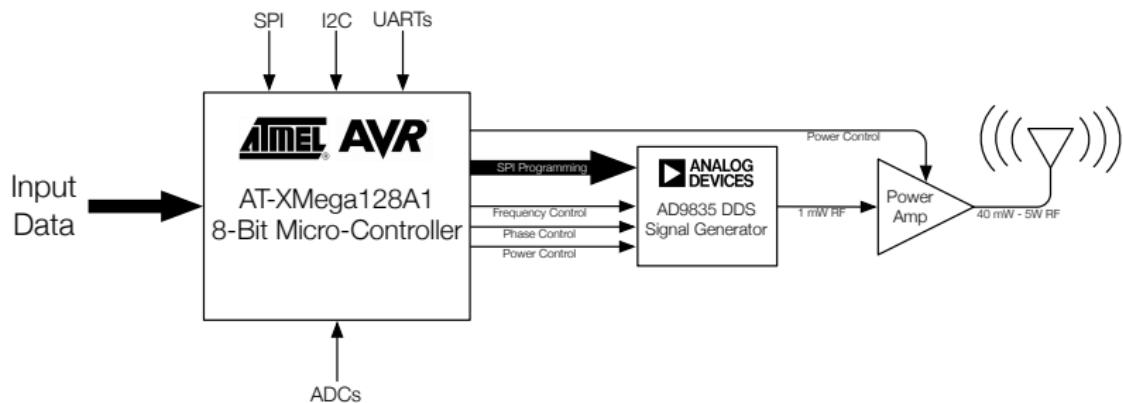
- ▶ Project scope expanded mid-year to include other applications.
- ▶ Initial Constraints still used.
  - ▶ Low Temperature Operation
  - ▶ Low Power Consumption
- ▶ Can be used in a huge amount of applications!



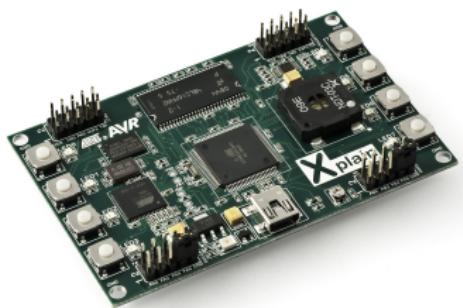
# Hardware & Software Overview

- ▶ Modular Design & Construction

# Hardware & Software Overview



# CPU - Atmel ATXmega128A1



## Atmel XPlain Development Board

- ▶ Atmel ATXmega128A1 Micro-Controller, clocked at 32MHz
- ▶ 3.3v Operation.
- ▶ 8MB SDRAM, 8MB NAND Flash Memory
- ▶ Low Power Consumption - 18mA @ 32MHz, 1.4mA @ 2MHz,  $1.16\mu\text{A}$  Power-Save

## Signal Generator - Analog Devices AD9835

- ▶ Original intention was to use an AD9834, AD9835 had almost identical power requirements.



### Analog Devices AD9835

- ▶ Can generate Sine-waves between 1Hz - 25MHz.
- ▶ 2 programmable (via SPI) frequency registers.
- ▶ Dedicated pins for switching between registers.
- ▶ Using 16MHz SPI clock, can reprogram at 7500Hz.
- ▶ Draws approx 40mA @ 5V while running. 50MHz Oscillator accounts for most of this.

# Power Amplifier

- ▶ All operate from 12V Supply.
- ▶ AD8008 Op-Amp based pre-amplifier - 40mW output, wide bandwidth.
- ▶ Class C NPN Transistor Amplifier - 1W output.
- ▶ Class E MOSFET Power Amplifier - 5W output.

# Power Supply

## Supply Requirements

- ▶ 12v, 5v and 3.3v rails are required.
- ▶ Linear Regulators are very in-efficient.
- ▶ Switch-mode Regulators used instead.

## Battery Power

- ▶ Powered from a 12V SLA for testing.
- ▶ For sub-zero use, Lithium-iron primary cells can be used.
- ▶ Lithium-thionyl chloride secondary cells can operate down to  $-60^{\circ}\text{C}$ .

# Software Overview

- ▶ Coded in C and C++.
- ▶ Libraries built first, more complex applications later.
- ▶ Morse, RTTY (FSK) and DominoEX modulation implemented.
- ▶ Data acquisition from onboard ADCs, UARTs, or I<sup>2</sup>C Devices.

## Morse Code & QRSS

- ▶ Morse Code at very slow speeds can be received over very long distances.
- ▶ Signals are pulled out of the noise floor with DSP techniques.
- ▶ Very low signal bandwidth.
- ▶ Not very useful for transmitting lots of data.
- ▶ Good for beaconing.

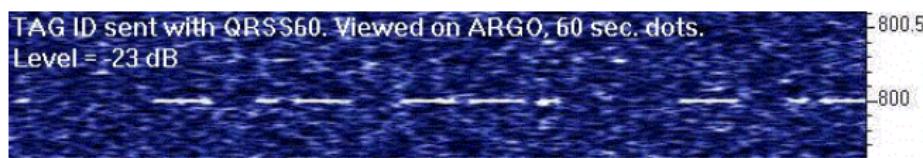


Figure: QRSS Morse Broadcast, signal level -23dB below the noise floor.

# RTTY (FSK)

- ▶ FSK Modulation, with start and stop bits.
- ▶ Implemented to operate between 50 and 300 baud (symbols/sec).
- ▶ Carrier Shift programmable from 170 to 425Hz.
- ▶ Plenty of existing software to decode RTTY (i.e. fldigi)

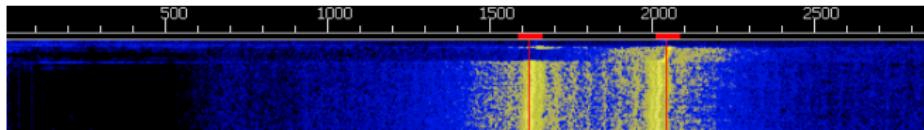
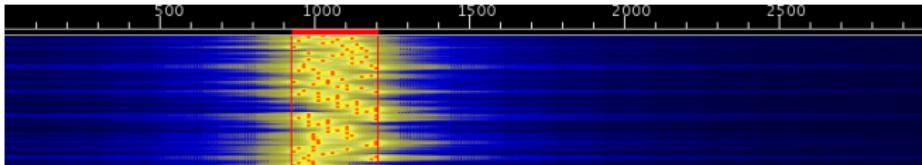


Figure: 300 Baud RTTY, with 425Hz Carrier Shift

## DominoEX (MFSK)

- ▶ The first MFSK-based mode implemented - utilises Incremental Frequency Shift Keying.
- ▶ Resistant to multi-path and doppler effects.
- ▶ 6 variations available, each with different symbol rates (3.9 to 29.5Hz) and bandwidths (173 to 524Hz).
- ▶ Data rates varying from 2 to 14 *characters* per second.



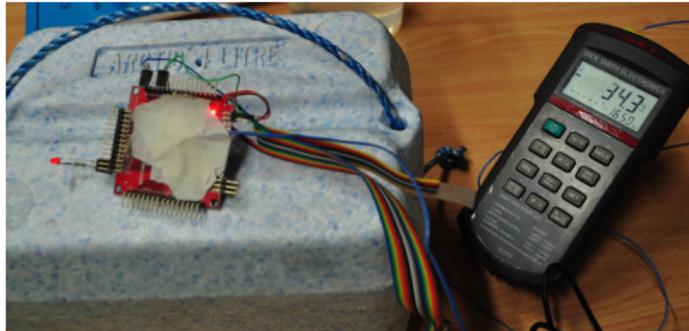
**Figure:** DominoEX8 - 7.8125 baud, 346Hz Bandwidth

# Software Testing

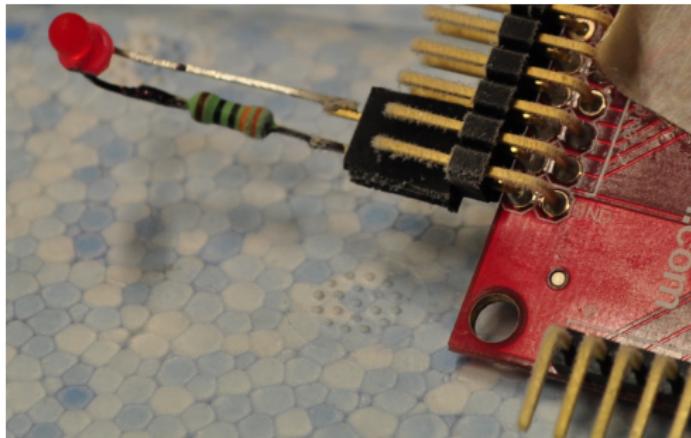
- ▶ AD9835 Libraries tested & working long before the XMega was purchased.
- ▶ Modulation libraries tested individually.
- ▶ Use carrier of 1KHz, and test with computer sound card.
- ▶ Fl-Digi data modem software used to de-modulate received data.

# Low Temperature Testing

- ▶ All major components rated to either  $-40^{\circ}\text{C}$  (AD9835) or  $-55^{\circ}\text{C}$  (XMega).
- ▶ Doesn't hurt to check!
- ▶ Dry Ice used to cool components to rated limits or below.



# Low Temperature Testing



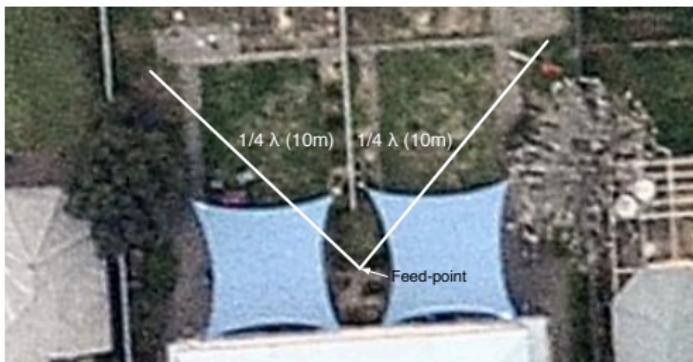
- ▶ AT-XMega's internal RC 32MHz oscillator drifts up to 33MHz at  $-55^{\circ}\text{C}$ .
- ▶ AD9835's output only drifts up by  $\sim 300\text{Hz}$  at  $-40^{\circ}\text{C}$ !

# Amplifier Testing

- ▶ Initially tested using  $50\Omega$  dummy load.
- ▶ Yaesu FRG-8800 Shortwave receiver used to verify RF transmission.
- ▶ Balun and half-wave dipole for 40m (7MHz) operation constructed.



# Amplifier Testing

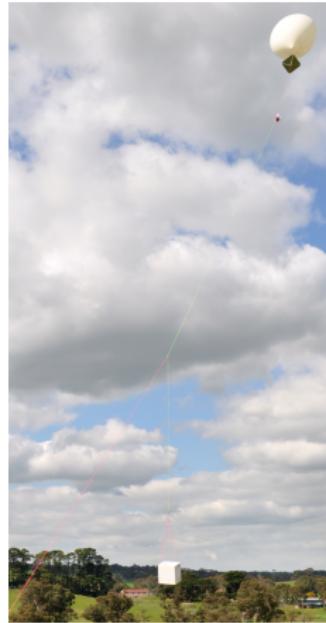


- ▶ Dipole arranged in horizontal 'V' configuration, approx. 2m above ground.
- ▶ Tested on amateur 40m band - Haven't been able to confirm skywave.
  - ▶ Required a licensed amateur operator to be present.
  - ▶ License examination to be taken tomorrow!

# Example Application - HAB Telemetry Transmitter

## Amateur High Altitude Ballooning (HAB)

- ▶ Aims to set height / distance records for balloon flights.
- ▶ Record images from high above the Earth's surface.
- ▶ Some form of telemetry system used to track balloon in flight.
- ▶ 433MHz Single-Sideband Transmissions commonly used.



## Example Application - HAB Telemetry Transmitter



- ▶ Local Amateur HAB group - **Project Horus**
- ▶ Have offered to fly a prototype transmitter on the 10th of October.
  - ▶ GPS Receiver, for positioning information
  - ▶ Temperature Sensors

# Prototype

- ▶ System 'Motherboard'
  - ▶ XMega
  - ▶ AD9835 DDS VFO
  - ▶ UBlox5 GPS Module
  - ▶ I<sup>2</sup>C Temperature Sensors
- ▶ Amplifier Module

# Future Work

- ▶ Finish PCB Main-Board Design.
- ▶ Characterise amplifiers.
- ▶ Perform long-distance testing.
- ▶ Make a deliverable prototype.

# References

Saft *Lithium-thionyl chloride (Li-SOCl<sub>2</sub>) Cell Range*

[http://www.saftbatteries.com/Produit\\_LSH\\_cell\\_range\\_303\\_8/Default.aspx](http://www.saftbatteries.com/Produit_LSH_cell_range_303_8/Default.aspx)

# Question Time

Any Questions?