

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.

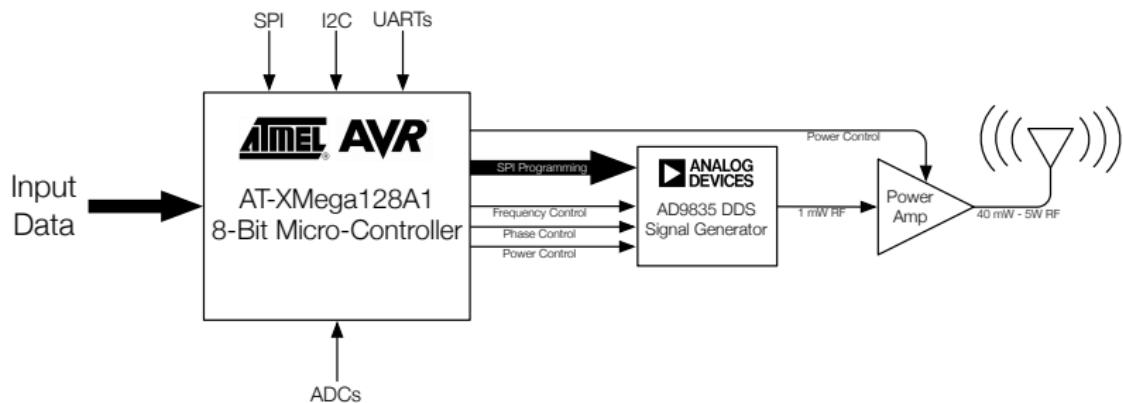
- ▶ Project scope expanded mid-year to include other applications.
- ▶ Initial Constraints still used.
 - ▶ Low Temperature Operation
 - ▶ Low Power Consumption
- ▶ Can be used in a huge amount of applications!



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°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, I²C and 1-Wire Devices.
- ▶ Some libraries ported to the XMega from the Arduino project.

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.

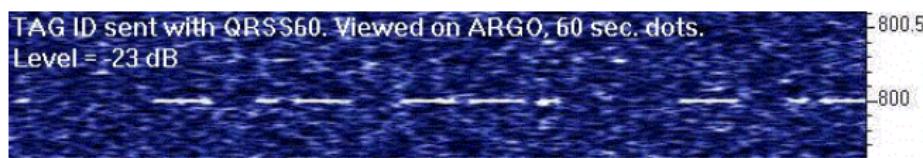


Figure: QRSS Morse Broadcast, signal level -23dB below the noise floor.

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)

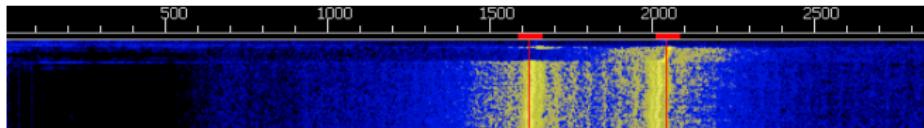


Figure: 300 Baud RTTY, with 425Hz Carrier Shift

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.

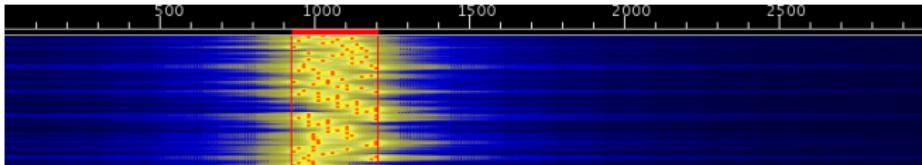


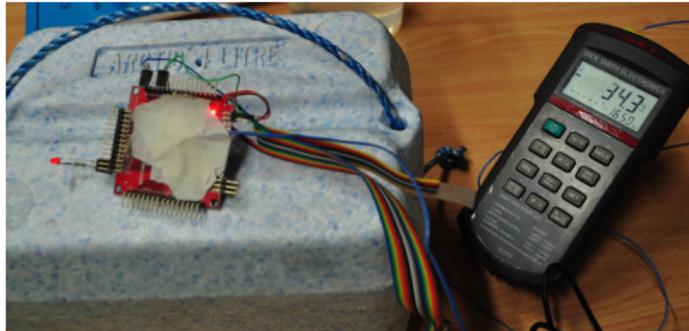
Figure: DominoEX8 - 7.8125 baud, 346Hz Bandwidth

Software Testing

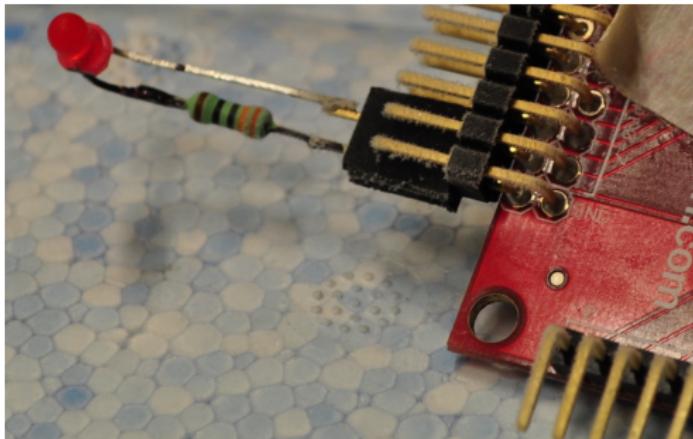
- ▶ AD9835 Libraries tested & working long before the XMega was purchased.
- ▶ Modulation libraries tested individually.
- ▶ Use carrier of 1KHz, and test with computer sound card.
- ▶ Fl-Digi data modem software used to de-modulate received data.

Low Temperature Testing

- ▶ All major components rated to either -40°C (AD9835) or -55°C (XMega).
- ▶ Doesn't hurt to check!
- ▶ Dry Ice used to cool components to rated limits or below.



Low Temperature Testing



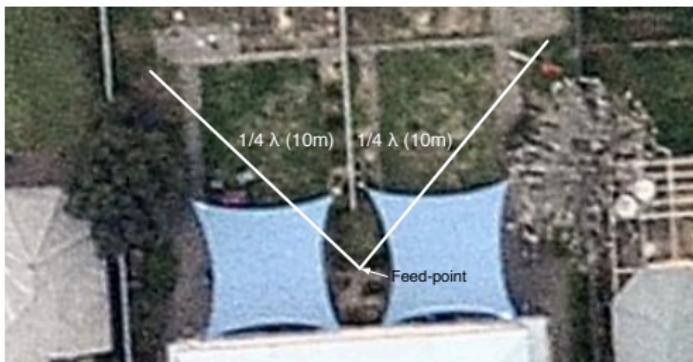
- ▶ AT-XMega's internal RC 32MHz oscillator drifts up to 33MHz at -55°C .
- ▶ AD9835's output only drifts up by $\sim 300\text{Hz}$ at -40°C !

Amplifier Testing

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



Amplifier Testing

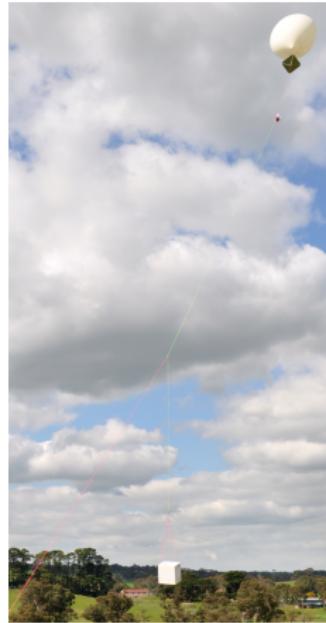


- ▶ Dipole arranged in horizontal 'V' configuration, approx. 2m above ground.
- ▶ Tested on amateur 40m band - Haven't been able to confirm skywave.
 - ▶ Required a licensed amateur operator to be present.
 - ▶ License examination to be taken tomorrow!

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
 - ▶ DS18B20 1-Wire 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-SOCl₂) Cell Range*

http://www.saftbatteries.com/Produit_LSH_cell_range_303_8/Default.aspx

Question Time

Any Questions?