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A Radio Relay System for Remote Sensors in the Antarctic

Final Seminar

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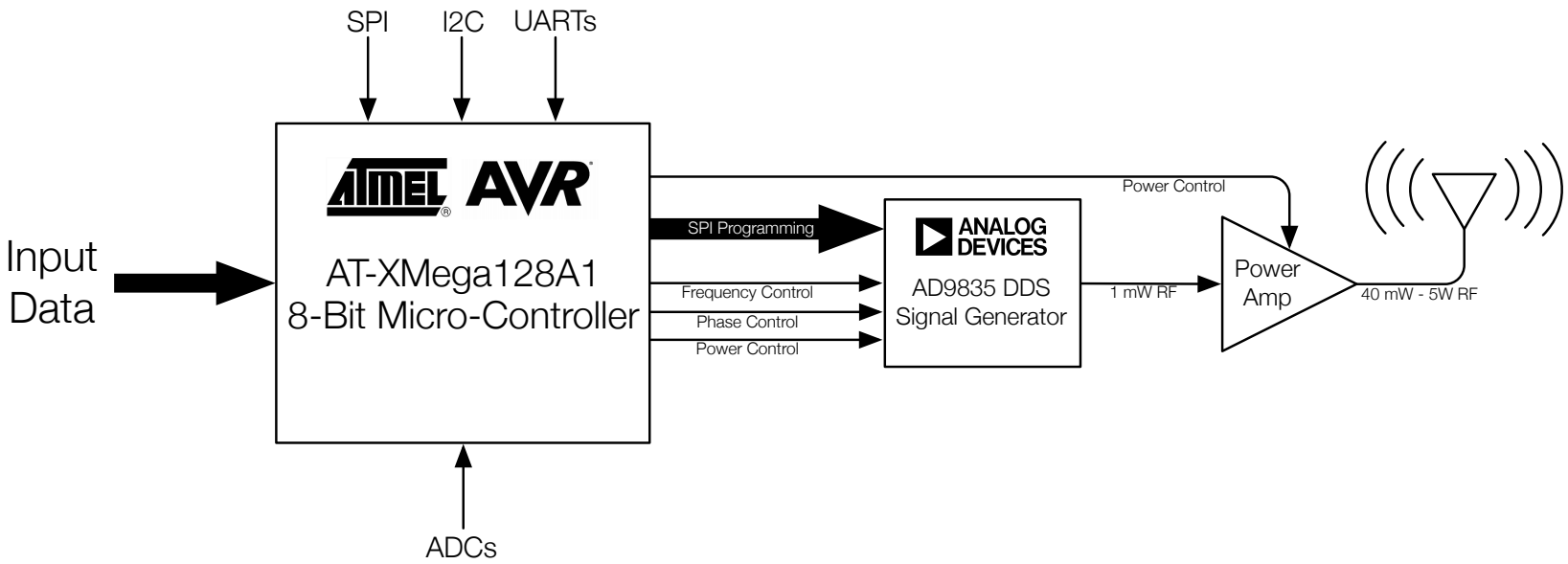
Motivation

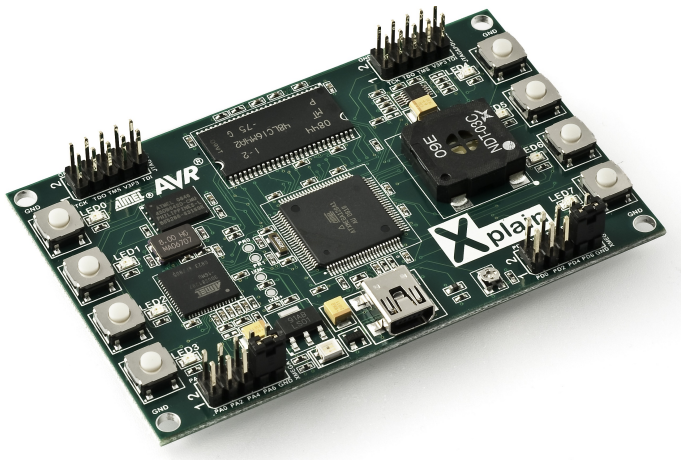
Aim - Design and build a low power HF data transmitter for use in an antarctic remote sensor application.

- 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



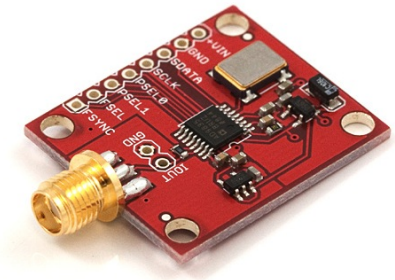
CPU - Atmel ATXmega128A1



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, 1.16μA Power-Save

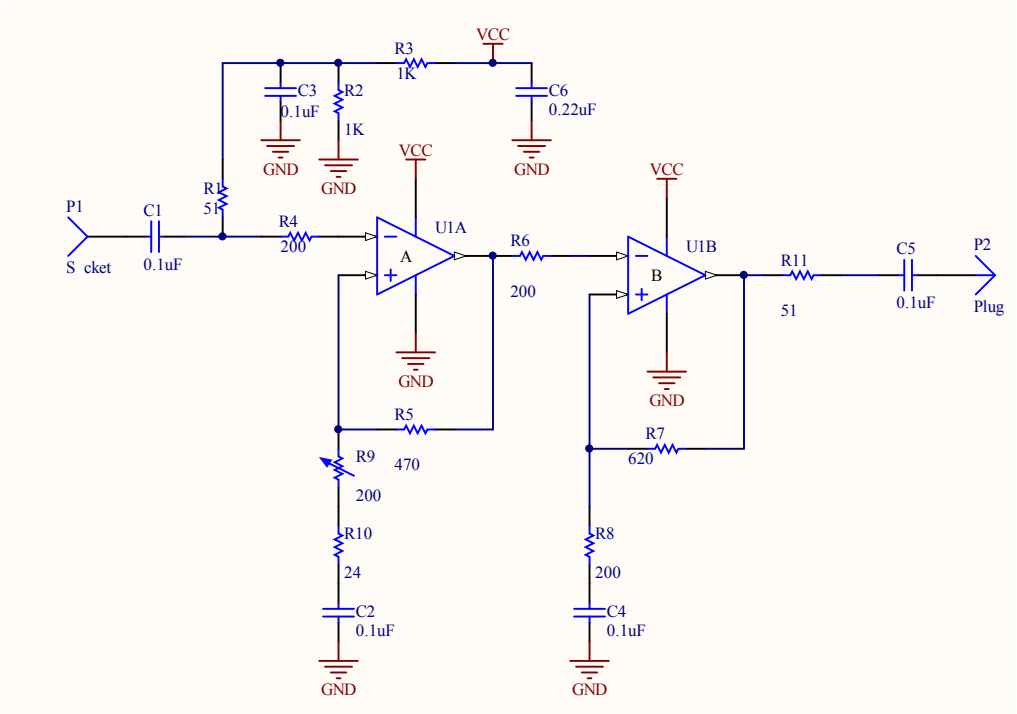
Signal Generator - Analog Devices AD9835



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

Power Amplifier - AD8008 40mW Amp



- Approx 13dB gain.
- Wide bandwidth - flat gain over 1 to 30MHz.
- Draws 38mA @ 12V - 450mW! *Very* inefficient!

Power Amplifier - Towards More Power

Class C NPN Transistor Amplifier

- Using 2N4427, approx 1W output.
- Will require multiple stages.
- Approx 60% Efficiency.

Class D/E MOSFET Power Amplifier

- Comparator produces PWM to drive IRF510's gate.
- Approx 5W output.
- >80% Efficiency

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.
- Multiple modulation modes implemented.
- Data acquisition from onboard ADCs, UARTs, external I^2C 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.

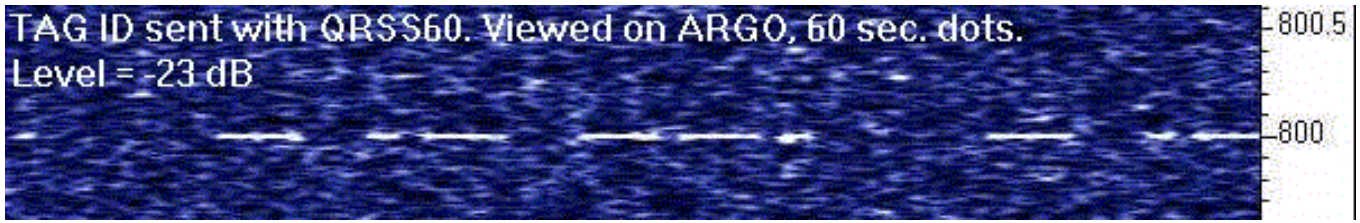


Figure: QRSS Morse Broadcast, signal level -23dB below the noise floor.

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)

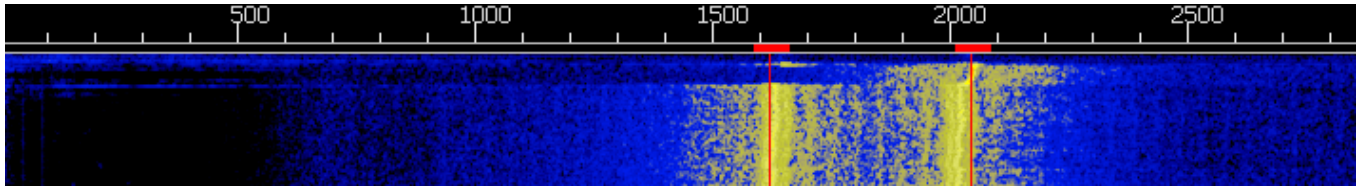


Figure: 300 Baud RTTY, with 425Hz Carrier Shift.

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).
- User throughput from 3 to 16 *characters* per second.

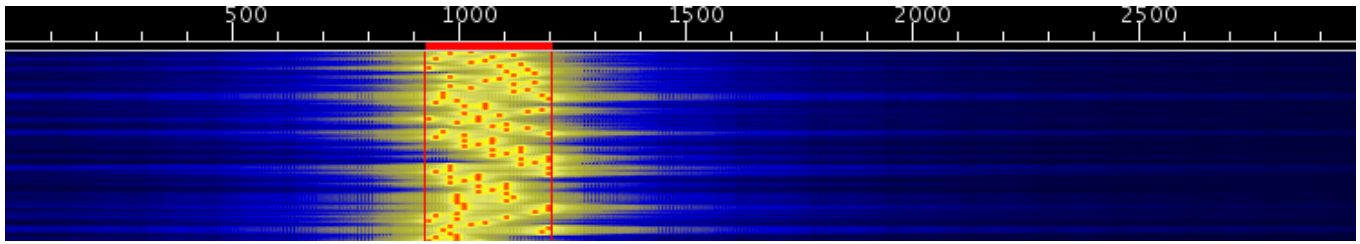
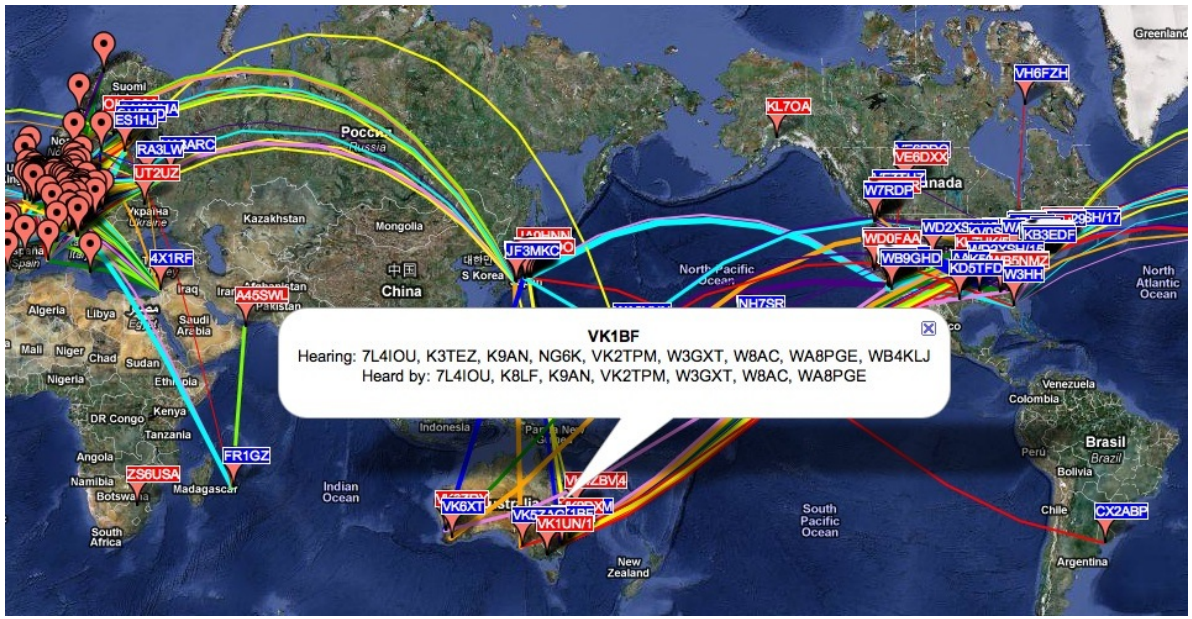


Figure: DominoEX8 - 7.8125 baud, 346Hz Bandwidth

WSPR - Weak Signal Propagation Network

- Uses MEPT-JT: 1.46 baud MFSK-4 modulation with compression & strong FEC. 6Hz Bandwidth.
- Useful data can be recovered with a -29dB SNR!
- Online network of listeners - can check propagation quickly.

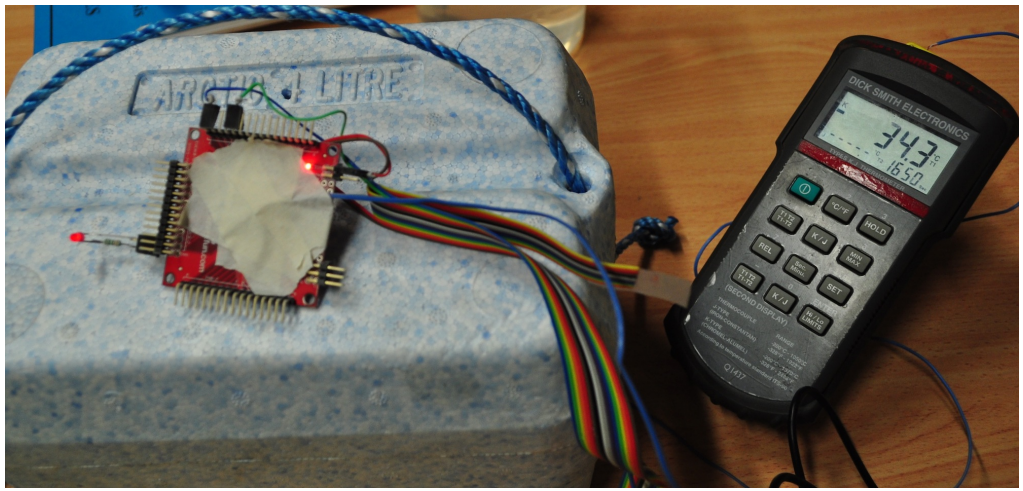


Software Testing

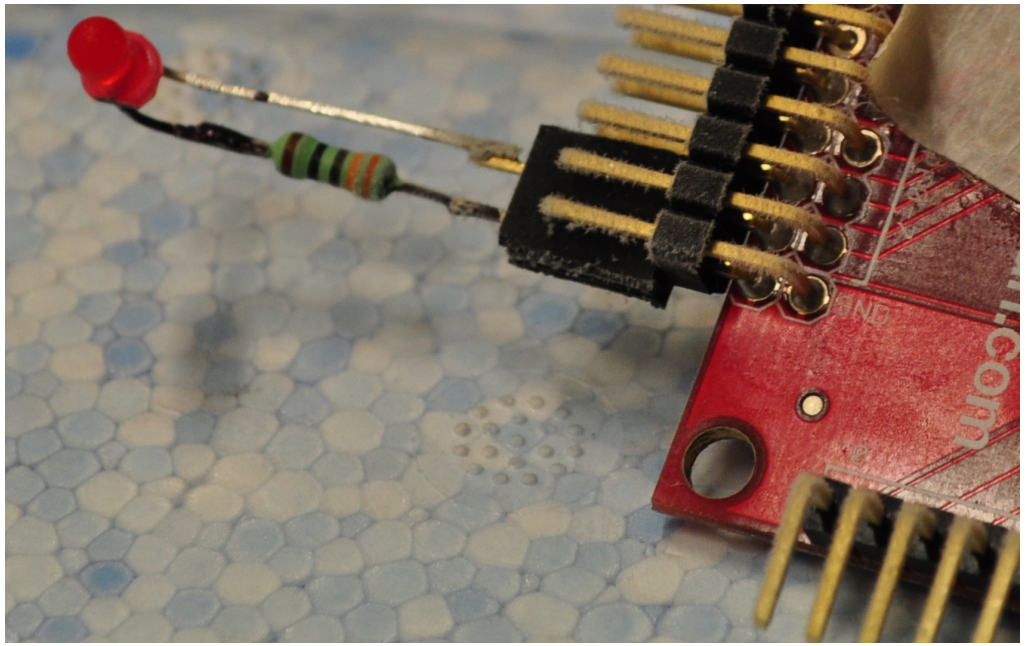
- AD9835 Libraries tested & working long before the XMega was purchased.
- Modulation libraries tested individually.
- Use carrier of 1KHz, and test with computer sound card.
- FI-Digi data modem software used to de-modulate received data.

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

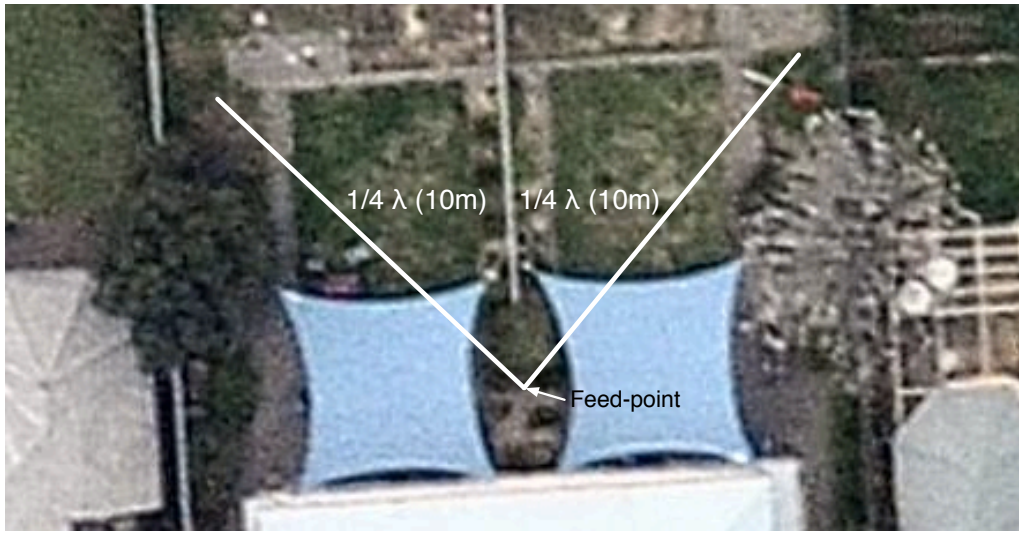


- Only fast temperature changes cause problems.
- AT-XMega's internal RC 32MHz oscillator drifts up to 33MHz at $-55°C$.
- AD9835's output only drifts up by $\sim$300Hz at $-40°C$!

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 ASAP!

Example Application - HAB Telemetry Transmitter

- Local Amateur HAB group - **Project Horus**
- Have offered to fly a prototype transmitter tomorrow!
- Inputs:
  - GPS Receiver, for positioning information
  - Temperature Sensors

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.

Prototype

- System 'Motherboard'
  - XPlain Board
  - AD9835 DDS VFO
  - UBlox5 GPS Module
  - DS18B20 1-Wire Temperature Sensors
- Amplifier Module (40mW AD8008 Amp)
- 1:1 Balun
- Half-Wave Dipole Antenna
- Lithium Primary Batteries

Work to be done

- Finish High Power Amplifiers.
- Skywave testing.
- PCB mainboard & deliverable design.

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Management

- Original project schedule was very optimistic...

Meetings

- Weekly meetings with project supervisor.
- When supervisor was away, regular communication via e-mail.

Budget

- Approx $150 of $250 budget spent.
- Main costs were breakout & development boards for fast prototyping.

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References

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- Saft *Lithium-thionyl chloride (Li-SOCl2) Cell Range*
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- Hartwell. RM, 2006 *Argo QRSS Viewer*
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Demonstration & Questions

Any Questions?