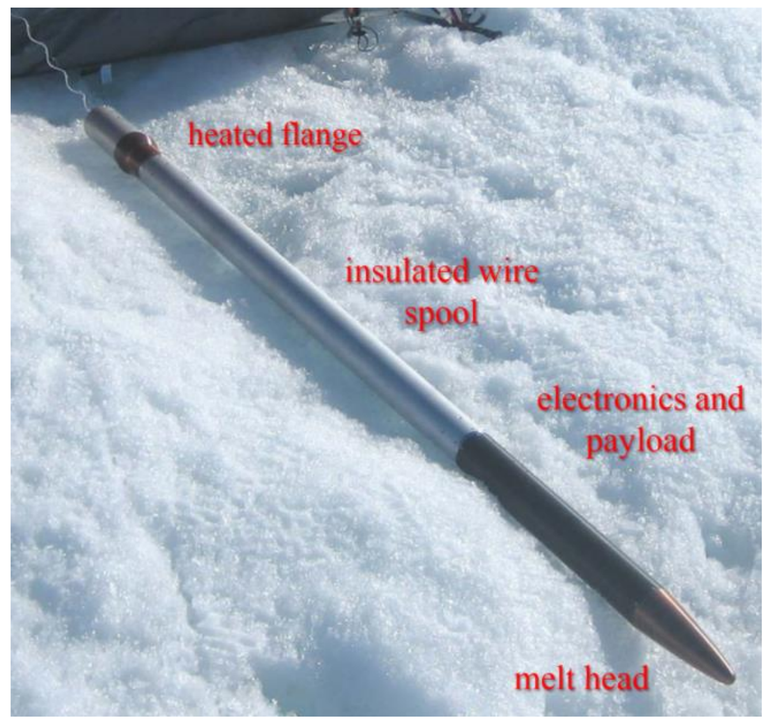
MEASURING THICKNESS OF A MELT JACKET AROUND A MELT PROBE DECENDING THROUGH GLACIAL ICE

STUDENTS: NICHOLAS IAROSLAVTSEV, ZEYU YE, FORREST MILLER

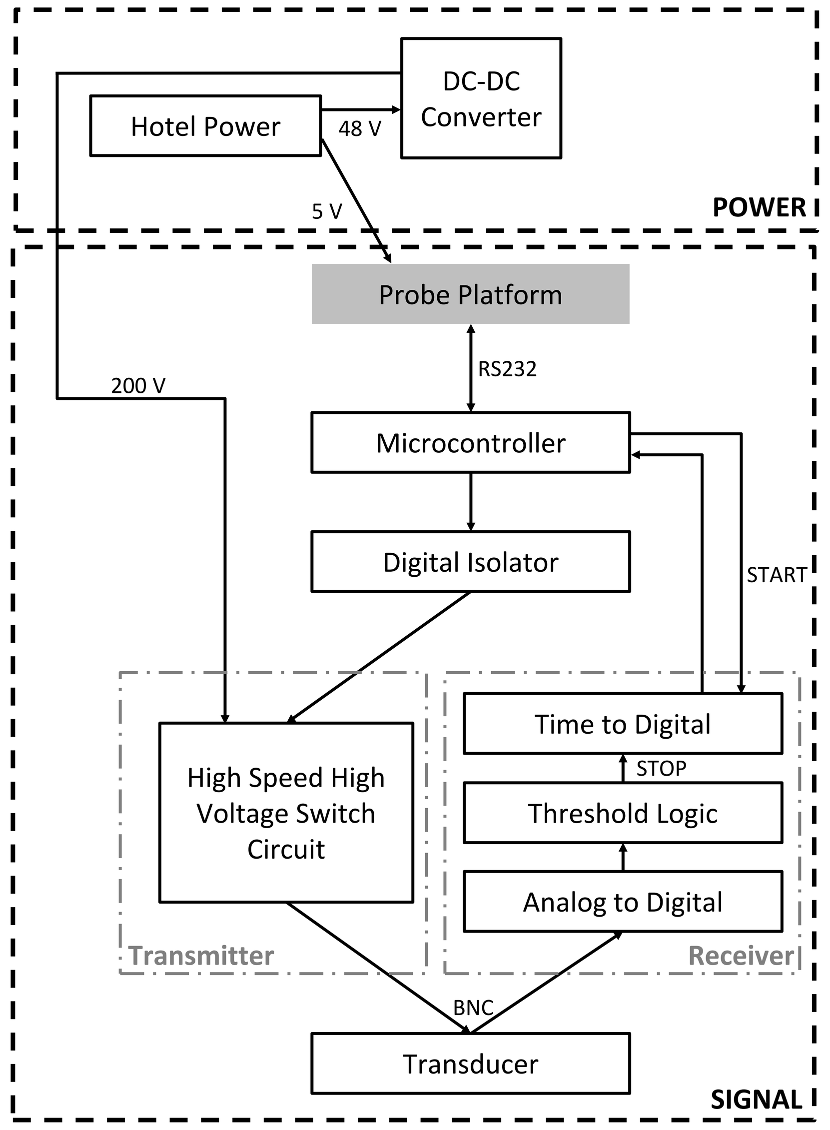
Background

- University of Washington Applied Physics Laboratory (APL) and NASA Jet Propulsion Laboratory (JPL) have made a melt probe that has been tested to work in Greenland.
- We want to test this in Antarctica, for use on Europa/other icy worlds in the solar system.
- Under the ice, the "melt jacket," which is formed around the melt head, may freeze the probe deep under the ice.
- The size of the melt jacket should be measured, using piezoelectric transducers, and sent to the processor within the probe.
- Our solution must fit within the probe and work with JPL's transducers.



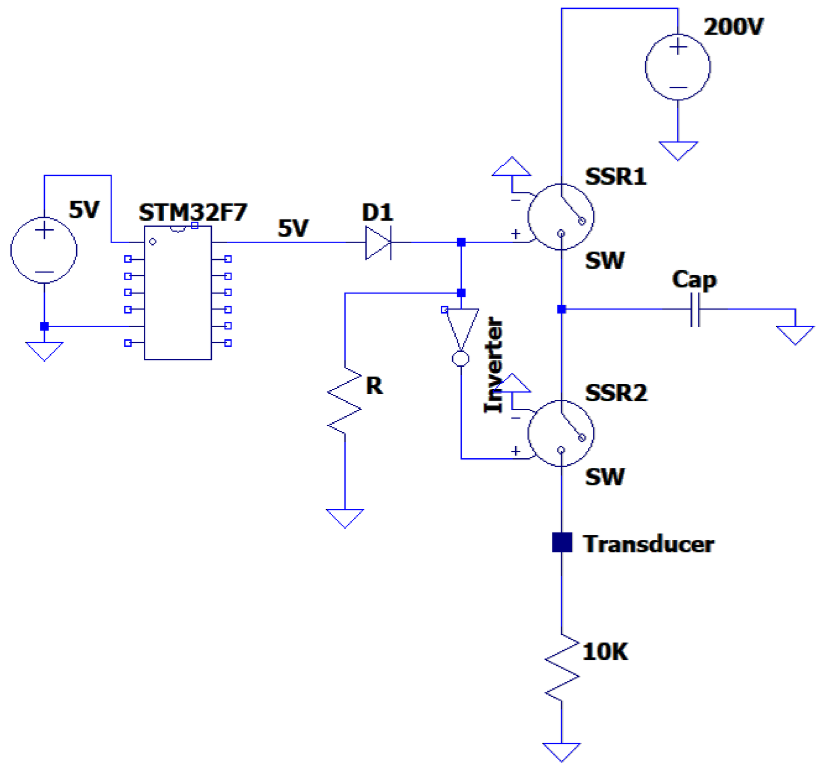
Design Overview and Features

- Usually, a melt jacket has a size of around 1 mm, which requires our pulse to be as short as possible in order to get better resolution.
- JPL chose a 20 MHz transducer which requires a single pulse excitation with negative high voltages [1].
- The communication between this subsystem and the central system of the probe is based on RS232, which means that we should process the signal within our design and only upload the distance results.
- In order to measure the waveform, we should sample it with an analog-to-digital converter (ADC) running at a frequency of at least two times of its.



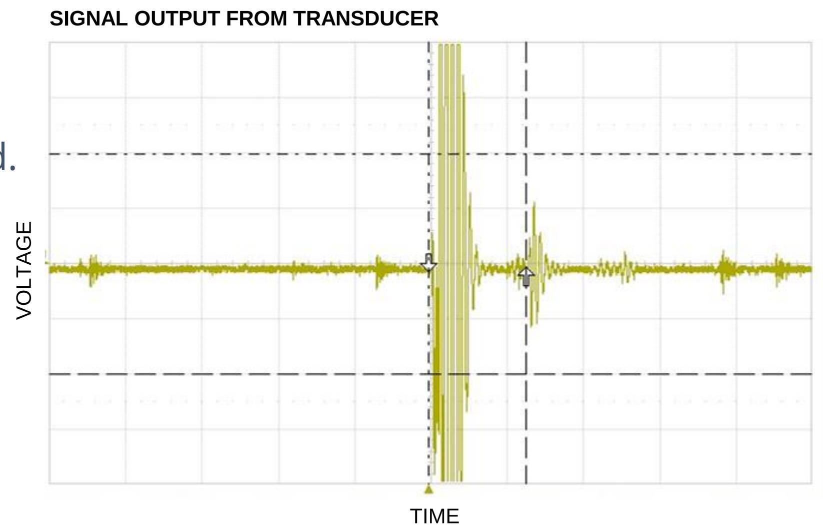
Transmitter Circuit

- Since the melt jacket changes its shape slowly, we could save calculation resources by reducing the frequency of the scan, and the intervals between two scans could be several seconds.
- Instead of using a timer to provide the excitations for our transducer by controlling its duty cycles, we chose a microcontroller to get more flexibility.
- This choice also allows the subsystem to response to commands from the platform easily and make our product more extendable.
- GPIO pins from the microcontroller only generates 3.3 V and is no enough to drive the transducer
- We use the small voltage to control two solid state relays to generate the required excitation behavior.
- The hotel power from the probe is 48 V, and it could drive a high-voltage op-amp to amplify our 5 V voltages up to its rail voltage, but we need a DC-DC converter to boost it to 200 V and let it charge a capacitor.
- Our design could create a pulse of about 600 μs duration.



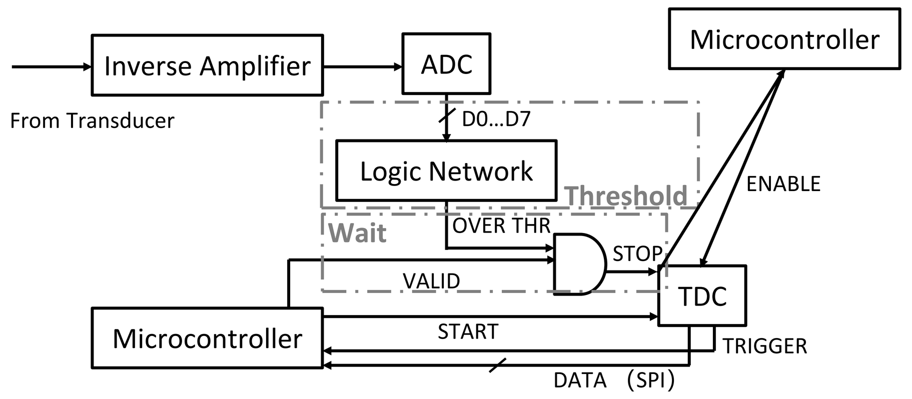
Signal Analysis

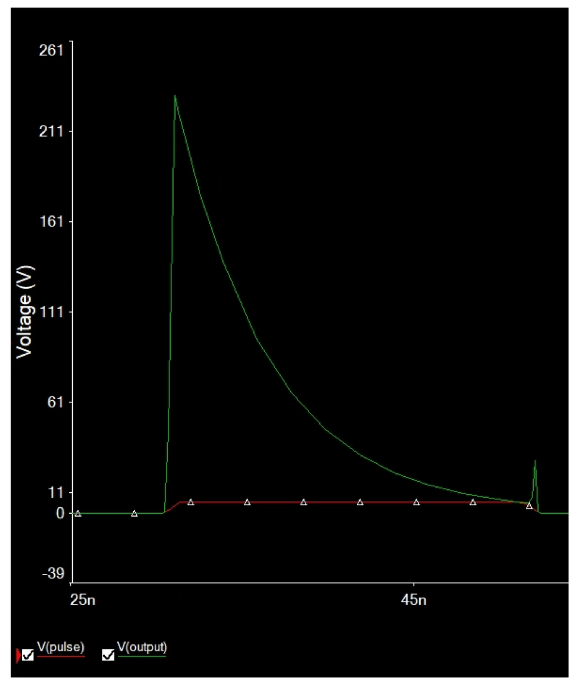
- Our transducer has both input and output on the same BNC cable, which makes necessary for us to study how the signal looks like on the receiver within one cycle.
- The left arrow shows a start of a large oscillation, which is cased by our excitation, which is also the start of our timing.
- The left arrow indicates the start of the echo, which is the stop of our timing.
- Other noises are small compared to the two discussed above, so they could be eliminated from our algorithm by setting a threshold.
- The larger oscillation in the figure is comparable to our interested signal, and it is caused by the artifacts after an excitation on the transducer, which could not be eliminated.
- The magnitudes of artifact signals decay exponentially. If we have a higher frequency, we should be able to speed up this process.
- To recognize the start of the echo signal well, we should set a minimum of our effective measure range to avoid this area, and only take data after it drops to low enough.



Receiver Circuit and Calibration

- Our design of using a microcontroller in the transmitter encourages us to use the same chip for taking our data from the signal to maximize the usage.
- To find the start point of the echo signal, we set a threshold and monitor when the trace passes trough the threshold for the first time after the excitation.
- The only interference comes from the artifact, but its pattern is identical after each excitation and independent from the echo signal.
- By doing experiment, we could study the artifact pattern well and the decay rate.
- Then, we could set up two parameters:
  1. Waiting time: time elapsed from when the microcontroller pull the GPIO to HIGH to when the magnitudes of artifact signals drop below 50% of our voltage threshold.
  2. Voltage threshold: the minimum voltage which would be considered as an effective reflected signal.
- The voltage threshold is determined by taking the peak voltage at the largest distance we want to measure and would determine our logic combination on the 8-bit analog-to-digital converter output.
- To take the waiting time into account, we let our microcontroller send another pulse in a different I/O pin when it has waited for this amount of time after it emits the first pulse, and this signal would enable the logic output and prevent the effects of artifacts.
- Any constant delays in our system does not affect our performance because the relationship between the time and the distance is linear, and all the delays would be collected in a constant.





- Microcontroller pull down VALID after the waiting time, pull down ENABLE after a STOP, and recover after the SPI data has been received.
- The excitation discharge controlled by the microcontroller is shown on the right.

Future Work, References, and Acknowledgments

- Replace our development board with self-designed PCB board to save space.
- More studies should be focused on the reflections from curved surfaces, such as bubble-shape melt jackets.

[1] Panametrics ultrasonic transducers: wedges, cables, test blocks, Olympus NDT Canada Inc., Québec, Canada, 2016

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