Phasemeter

General Description: The phasemeter (PM) is a digital embedded system designed to measure the phase of a MHz frequency oscillation with a precision of 0.1 μCycles/(√Hz) at Fourier frequencies of 1 Hz to 0.1 mHz. These design constraints are defined by the science requirements of the NASA-Laser Interferometer Space Antenna (LISA) project.

Design Details:
Design Constraints:
- Measure the phase of a 1-20 MHz electronic oscillation with a 0.1 μCycles/(√Hz) precision
- Consistently generate, store, and transmit the measured data with a 64-bit precision at a 10 Hz rate
- Understand noise sources and define a functional relationship with respect to the signal characteristics

Implementation: The PM is designed using a digital embedded system with ADC sampling capabilities, FPGA fixed point processing filters, and floating-point MPC for data-handling and TCP/IP communications.

Hardware:
- Pentek Inc. Model 4205: VIM/PMC Carrier-card, 1 GHz MPC7457 Processor, 1 GB SDRAM
- Pentek Inc. Model 6256: Four Channel 105MHz A/D Daughter-card w/ XC2VP50 Xilinx FPGAs

Cost: $25,630.00 per 4-channel measurement system (2 Pentek Carrier + Daughter-card systems)

Design Requirements & Complications:
- Understand MPC processes and threads to control phasemeter measurements, perform data-handling and communication
- Program FPGA using VHDL with digital phase lock loops to track and generate the signal phase
- Quantization error of 32-bit VIM is greater than 0.1 μCycles/(√Hz) precision; 64-bit readout via data-packing required
- Phase roll-off of RF transformer filter response causes dispersion noise; RF transformers de-soldered and replaced

Associated Project/Client: Laser Interferometer Space Antenna Laboratory at the University of Florida

Duration: January 2005 – May 2012 (Ongoing research)

For more information:
UF-LISA Phasemeter: http://www.phys.ufl.edu/research/lisa/phasemeter.shtml

Ongoing AEI Phasemeter (research colleague’s): http://iopscience.iop.org/1742-6596/154/1/012017
Electronic Phase Delay Unit

**General Description:** The electronic phase delay (EPD) unit is designed to simulate the laser light travel transmission between the space-craft as would be the case on the NASA-Laser Interferometer Space Antenna (LISA) project. Phasemeter information from MHz frequency signals must be delayed for 16.6 seconds, time-scaled to replicate the motion between the LISA space-craft, and regenerated in real time.

**Design Details:**

**Design Constraints:**
- Capture and delay phasemeter data for 16.6 seconds with a 64-bit precision
- Time-scale phase data to simulate inter-space-craft relativistic Doppler shifts
- Add processor generated signals to phasemeter information to simulate gravitational wave phase modulations

**Implementation:** The EPD unit is designed using a digital embedded system with ADC sampling and DAC regeneration capabilities. Multiplexed PM data is stored in 1 GB of SDRAM at a rate of 488kHz which delays the phase information while a floating-point MPC is used for data interpolation and calculating GW modulation information.

**Hardware:**
- Pentek Inc. Model 4205: VIM/PMC, 1 GHz MPC7457 Processor, 1 GB SDRAM - Carrier-card
- Pentek Inc. Model 6256: Quad 105 MHz A/D w/ XC2V1000 Xilinx FPGAs – VIM Module
- Pentek Inc. Model 6228: 4-Channel D/A, Digital Up-converter w/ XC2VP50 Xilinx FPGAs – VIM Module

**Cost:** $29,625.00 per 4-channel measurement system (2 Pentek Carrier, A/D, and D/A Daughter-card systems)

**Design Requirements & Complications:**
- Each channel requires 130 MB (16 bytes x 16.6 seconds x 488 kHz) of storage
- Phase data must be interpolated in real-time while simultaneously handling data-transfers between the daughter-cards.

**Associated Project/Client:** Laser Interferometer Space Antenna Laboratory at the University of Florida

**Duration:** January 2006 – May 2012

**For more information:**
- UF-LISA Interferometry Simulator:
  - [http://www.phys.ufl.edu/research/lisa/lisainterferometry.shtml](http://www.phys.ufl.edu/research/lisa/lisainterferometry.shtml)
  - [http://www.phys.ufl.edu/research/lisa/timedelay.shtml](http://www.phys.ufl.edu/research/lisa/timedelay.shtml)
Micro Air Vehicles (& MAV Patent)

General Description: The Micro Air Vehicle (MAV) project's primary goal is to design, construct, and flight test 6-24 inch unmanned surveillance aircraft. These MAV's were powered by lithium ion batteries, controlled by servo's, driven by micro motors/props, and carried on-board CCD video camera transmission capabilities. Their applications ranged from military surveillance to environmental health documentation.

Design Details:

Design Constraints:
- MAV must be able to be carried in a 6’ diameter cylinder
- MAV must be able to capture and transmit video data at distances of 5 miles
- MAV must be stable in flight for up to 30 minutes in 15+ knot winds
- MAV must be cost efficient to mass produce
- MAV must be durable and easily repairable in the case of a crash landing

Implementation: The MAVs are constructed from commercially available components which are mounted within a carbon-fiber body/wing structure. The essential design considerations include a light-weight aircraft with flexible, bird-like wings. The MAV body/wing structure is vacuum molded onto a CNC milled wing & body template to obtain the correct air-foil and provide the ability for easy mass reproduction. Each air-foil must be tested to ensure flight stability and to understand the MAV's in-flight characteristics.

Hardware:
- Body/Wing Structure: Carbon-fiber cloth epoxied, vacuumed, and baked onto a steel CNC milled form.
- Power Source: 3.7 Volt Lithium-Ion Batteries with a 400-1200mAh capacity.
- Motor: Assorted brushless motors, usually used for counter-weight vibrator drivers in cell-phones
- Propeller: Designed using variations of calculus to optimize the thrust in the low-Reynold's number thresh-hold.
- Aileron Actuators: Miniature stripped RC servos
- Video Camera & Transmitter: Stripped CCD camera & 2.4 GHz wireless transmitter/receiver

Cost: $400.00 - $800.00 per aircraft

Design Complications:
- Ridged wing structures are susceptible to wind gusts; adaptive bat-like air-foils are employed to improve aircraft
- 6-inch wingspan aircraft, although possible, are not stable; wings must fold and un-fold for aircraft storage
- Thrust magnitude vs. efficiency must be tested to improve flight-time to 30+ minutes
- On-board components must be stripped to reduce flight weight

Associated Project/Client: The University of Florida Micro Air Vehicle Project

Duration: June 2002 – December 2004

For more information:
Mavric Commercial MAV: http://www.youtube.com/watch?v=ZPt9gNCiY
Infrared 3D Surface Scanner

**General Description:** The Infrared 3D Surface Scanner was a project developed for the University of Florida Electrical Engineering Senior-Design class. This device is required to record, replicate, and mass-produce the 3-dimensional surface functions which define the MAV air-foils.

**Design Details:**

**Design Constraints:**
- The Infrared Scanner must be able to record a functional description of an air-foil's surface; \( z(x,y) \)
- The scanner must have a domain of 12 inches in both the \( x \) and \( y \) directions and an accurate range of 2 feet

**Implementation:** The scanner will use a PIC-processor to control stepper motors and actuate an infrared distance meter. The infrared voltage readout is ADC converted to a digitized distance value and recorded for one point in a 100x100 point grid. The stepper motors move the infrared meter through the 2-D \( x \)-\( y \) 100x100 point surface. The distance information is serially communicated to a personal computer and displayed as a 3D surface image.

**Hardware:**
- Construction Supplies: Lumber, gears, steel driver rods, etc.
- PIC Processor and PCB: Single layer PCB with PIC processor, meter input, motor control output, & serial comm. output port
- Stepper Motors: Mounted on scanner to control the motion of the infrared distance meter through the grid
- Infrared Distance Meter: Mounted on driver rods; generates a voltage proportional to distance

**Cost:** $260.00 (materials cost)

**Design Complications:**
- Infrared distance meter accuracy is limited and non-directional; Modifications to orient the infrared signal improves accuracy.
- Distance data must be accurately and continuously captured using a personal computer, then stored and displayed.

**Associated Project/Client:** The University of Florida Dept. of Electrical Engineering

**Duration:** May 2005 – July 2005

**Other Assorted Projects**

**UF-LISA PCB Analog Phase-lock Loop Controllers** – The PLL controller design schematics and simulations were produced in Eagle and used to produce commercially purchased 2-layer silk-screened PCBs. The components to populate the circuit were purchased from Digi-Key. The PLLs were constructed, tested, and used in the University of Florida LISA Simulator.

**UF-LISA Optical Bench** – The UF-LISA laser optical bench was designed and continually modified to test different portions of the NASA-LISA gravitational wave telescope project. Nd-YAG 1064 nm lasers were stabilized with ultra-stable glass reference cavities and used to construct the photo-detector signals required to test the essential details of the LISA mission.

**UF-LISA Arm Locking Controller** – The UF-LISA arm locking controller was designed using a digital embedded system purchased from Pentek Inc. The embedded system's on-board FPGA's were programmed with FIR controllers and used to produce the first hardware tests of previously published theoretical arm-locking stabilization controller.

**NASA-Goddard Optical Bench** – The NASA-Goddard optical bench was modified to implement dual electro-optical modulation laser side-bands. One free-space EOM and one fiber coupled EOM each produce a phase-modulated side-band and provide the ability to simultaneously stabilize and control the laser frequency.

**NASA-Goddard Digital PID Stabilization Controller** – The NASA-Goddard PID Controller was designed using Acromag Inc.'s programmable AX3065 digital signal processing controllers. The FIR zero-pole filter is designed through a Labview GUI and programmed to the AX3065's FPGA. A photodetectors DC laser power amplitude is compared against a constant voltage and used to track and control the laser power.