Instrumentation for diode laser spectroscopy using 32-bit microcontrollers and a Nexus 7 Android tablet

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Microcontroller and tablet choices

Motivation:

Rapidly improving low-cost tablets provide excellent interactive user interfaces and high-resolution graphics for $200 or less. Using 32-bit microcontrollers, sophisticated customizable lab instruments can operate in real time concurrently with data entry and display.

PIC32MX250 series microcontrollers from Microchip Technology

After evaluating several third-party development boards (including the MINI-32 described last year at DAMOP), I prefer custom designs with 40 MHz PIC32MX250 microcontrollers. They are available for about $4 in 28-pin and 44-pin versions that include 32-bit timer/counters, USB and SPI interfaces, 128 kB of memory and 32 kB RAM. Faster 50 MHz versions were recently announced.

The advantages of larger 80 MHz chips are outweighed by more convenient package outlines, operation without wait states, and much-improved flash memory read/write tolerance for storing modified user parameters. Output pins are configurable, and most are 5V-tolerant. Atomic 32-bit operations facilitate interrupt-based programming.

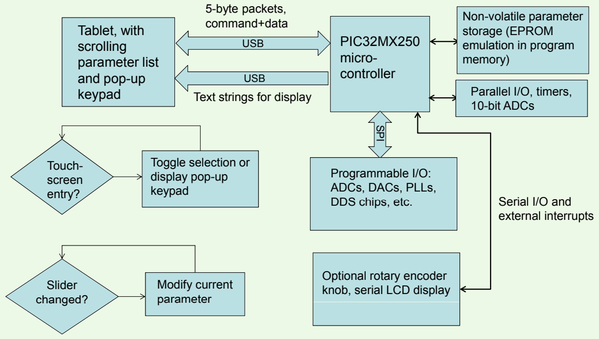
A free 'C/C++' compiler generates efficient and compact code, and a $45 PICkit 3 programmer performs in-circuit programming in just a few seconds.

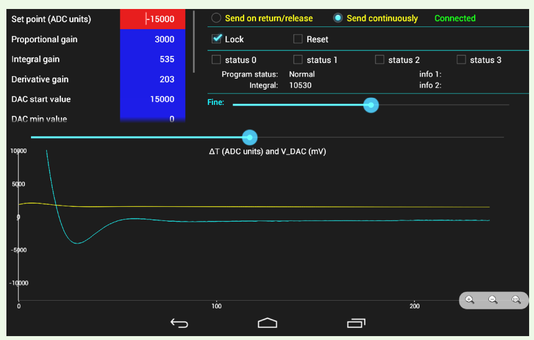
General-purpose Android interface with a $199 Nexus 7 tablet

A USB 2.0 "OTG" interface can operate in host mode with an Android tablet, providing continuous charging, or in device mode with a PC.

A single Java Android app, "MicroController", can be used for most purposes. It loads a scrollable parameter list and other data from the PIC32 when a USB connection is established using the Android accessory protocol.

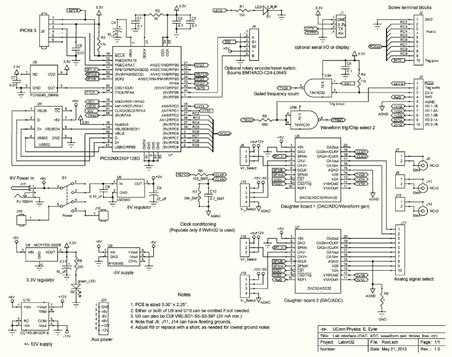
The fast high-resolution screen (1280 × 800) allows excellent real-time graphics and touch-screen input from sliders or a pop-up keypad.

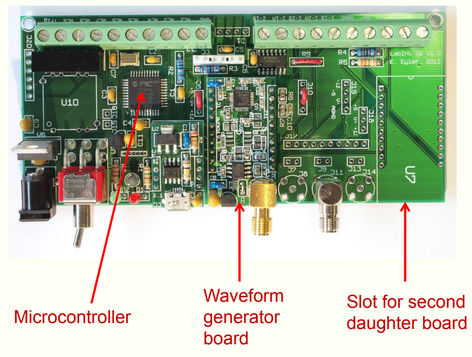




I. General lab interface

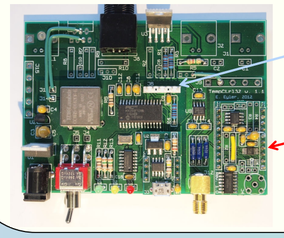
- Simple and accurate timing sequences with resolution to 12.5 ns. Remappable PIC32 pins add versatility.
- Two daughter board slots and flexible power supplies allow "mix and match" configuration.
- 50 MHz frequency/event counter using on-chip PIC32 timers. Accuracy of tiny FOX 924B clock chip ($3.76) is 2.5 ppm.

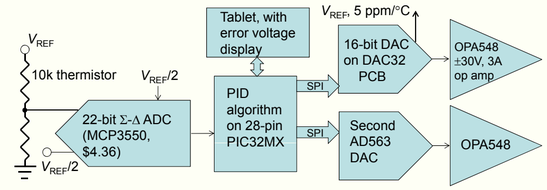




II: Precision temperature controller/PZT driver

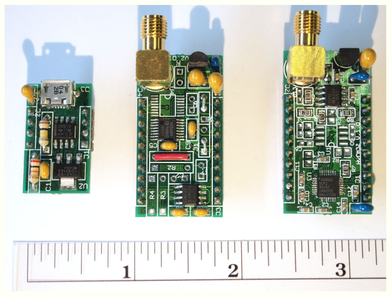
- The two independent op amp output stages can be used at up to 8A (with OPA549), or up to 350V (with PA340, just $12).
- 22-bit ADC has differential inputs, so no instrumentation amplifier is needed. Rate is just 15 Hz, but integrates. Single-measurement noise is about 0.25 mK with a standard 10k thermistor, stability is ~5 ppm/°C.

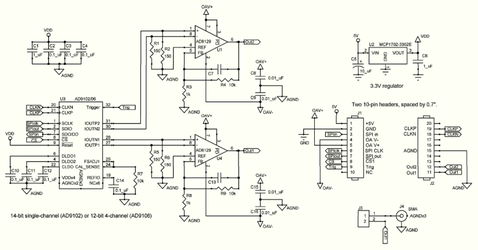




Daughter boards for peripherals

- At left is the tiny USB32 board (0.7" x 1") containing a USB power regulator, power switch, and a Micro A/B (OTG host/device) connector.
- At center, the DAC32 board (0.8" x 1.5") includes one or two low-cost dual 16-bit DACs (AD5689R, ~$9) and an uncommitted dual op amp with flexible feedback. On-chip references are accurate to 2.5 ppm/°C and update rate is up to 1 Msample/s.
- (Not shown) A pin-compatible board with an 8-channel 13-bit ADC (AD7329) has also been designed, but it often suffices to use the internal 10-bit ADC on the microcontroller. With data rates up to 1 Msample/second, and graphical display refresh rates of ~20 Hz on the Nexus 7 tablet, oscilloscope-like data display is possible.
- At upper right and in the schematic, a versatile arbitrary waveform generator and direct digital synthesizer is constructed on a pin-compatible board, using the remarkable new AD9102 (14-bit, one-channel, $23) or AD9106 (12-bit, 4-channel, $28). They can be clocked at up to 180 MHz, and contain 4096 words of on-chip waveform storage memory. The board also includes a pair of 200 MHz buffer amplifiers for voltage outputs.
- Reflow soldering is essential for the AD9102 and useful for all surface-mount chips. The $159 Aoyue 968A hot-air soldering station works very well.

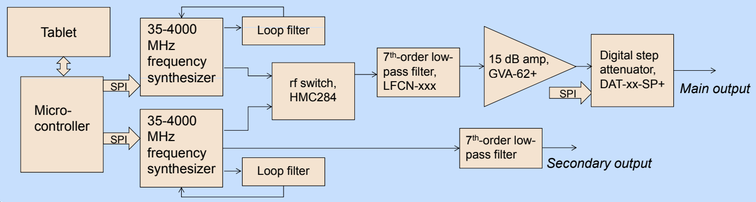


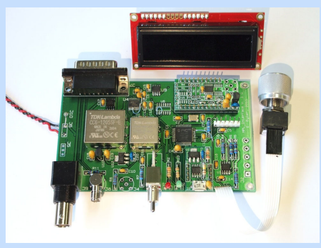


Schematic of arb. waveform/DDS board (photo at right, above).

III. Dual broadband frequency synthesizer and other designs

- The "**FreqSynth32**" board (diagram below) has been produced and software is in development. It uses one or two AD4351 PLL-based synthesizers, operable from 35–4000 MHz. The output is divided down from a 2-4 GHz internal VCO, so rapid frequency dithering is possible. Use of both synthesizers and a fast rf switch (5 nsec) allows phase-coherent frequency shift modulation at rates up to ~50 MHz.
- The **diode laser driver interface** (pictured at right) includes an optional 256-position rotary shaft encoder and a low-cost serial display, for use when the tablet is disconnected.
- A **diode laser frequency locking** board is under development.





For Further Information

Designs are available at http://www.phys.uconn.edu/~eyler/microcontrollers. A short descriptive article is in preparation.

An earlier sequencer using a 16-bit processor is described in E. E. Eyler, Rev. Sci. Instrum. **82**, 013105 (2011).

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