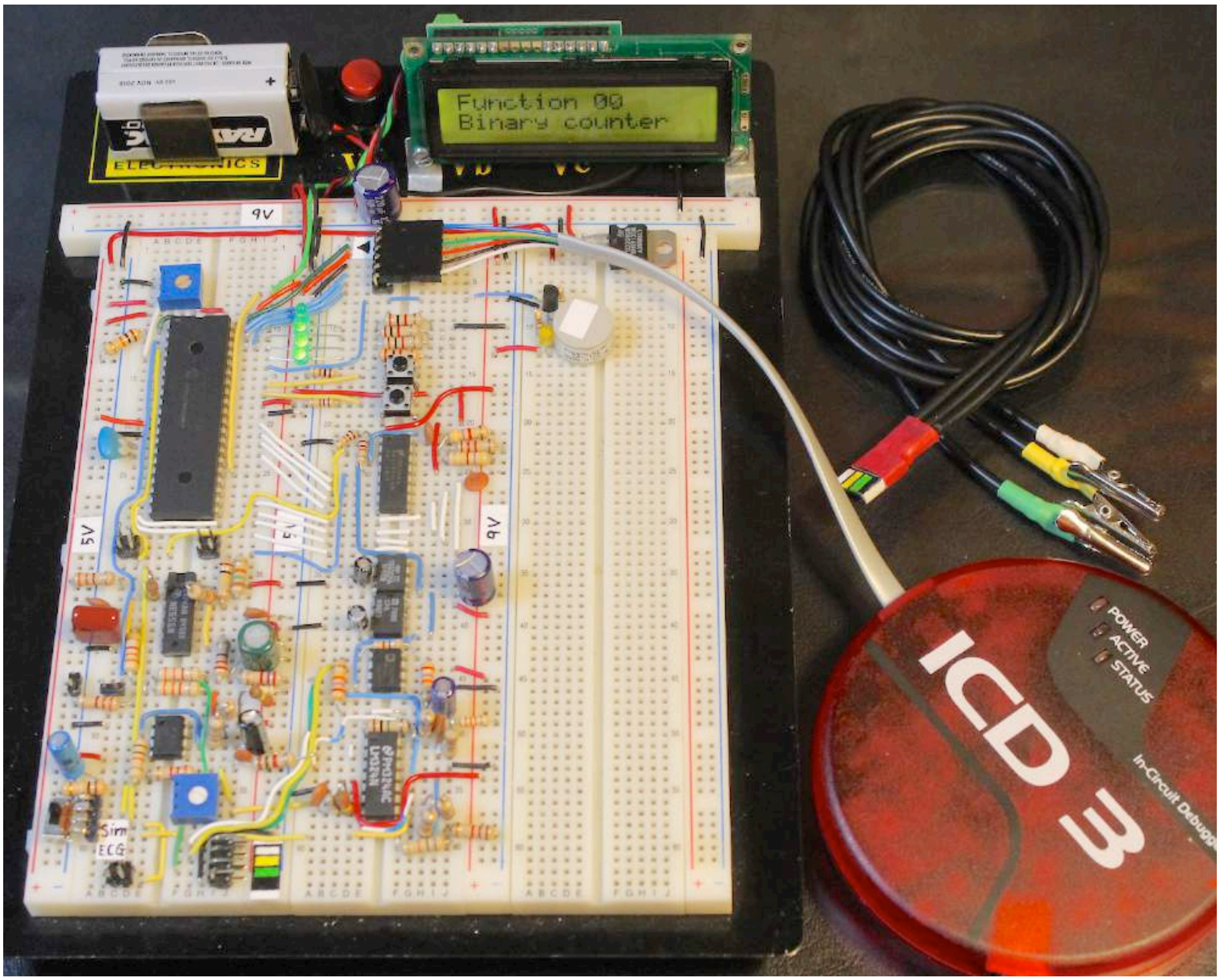
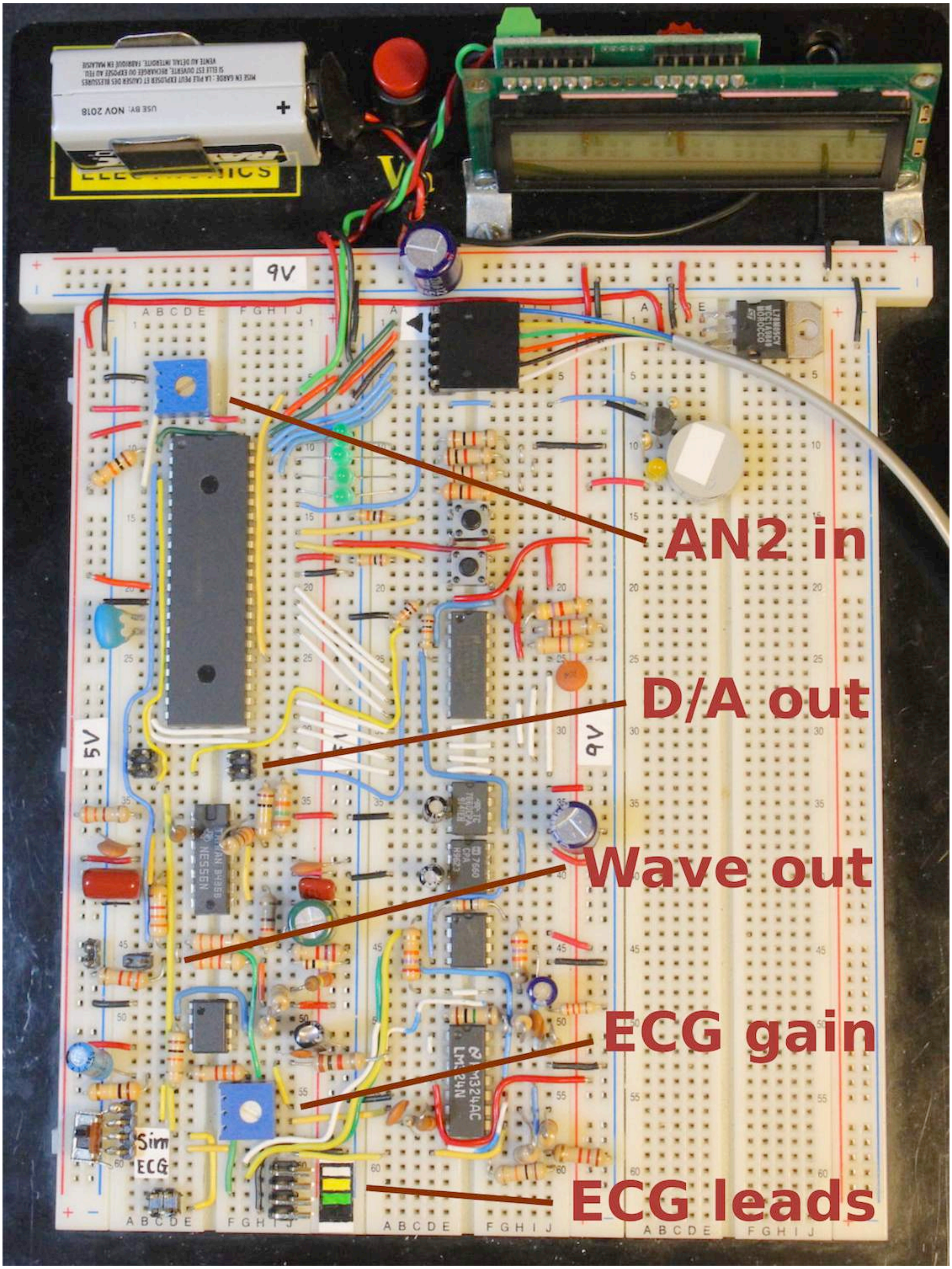
BME 361 Biomeasurement Laboratory Demonstration
Biomedical Engineering Program
University of Rhode Island
June 10, 2015

The functional units on this demonstration bread board include a PIC18F4525 processor, a D/A converter, an LCD display, a waveform/noise generator, an analog ECG simulator, and an ECG amplifier. The system is programmed with the MPLab IDE v8.89 via the ICD 3 programmer. The schematics, bill of materials, and C source code are attached in the end. The breadboard is shown below with the ICD 3 programmer connected. The ECG leads are also shown.

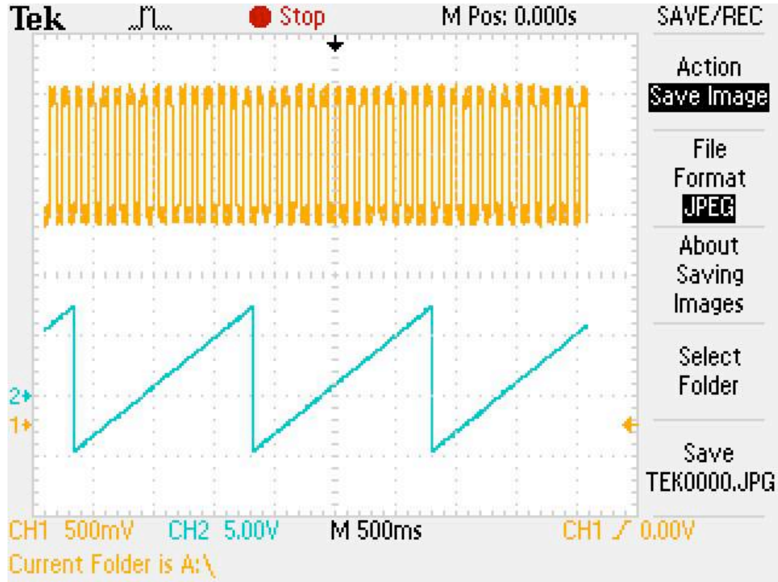


The picture on the next page shows the connectors for attaching two oscilloscope probes (D/A out and Wave out), the potentiometer for adjusting the inout voltage to A/D channel AN2, the potentiometer for adjusting the ECG gain, and the connector for attaching the ECG leads.


AN2 in
D/A out
Wave out
ECG gain
ECG leads
9V
5V
9V
Sim ECG

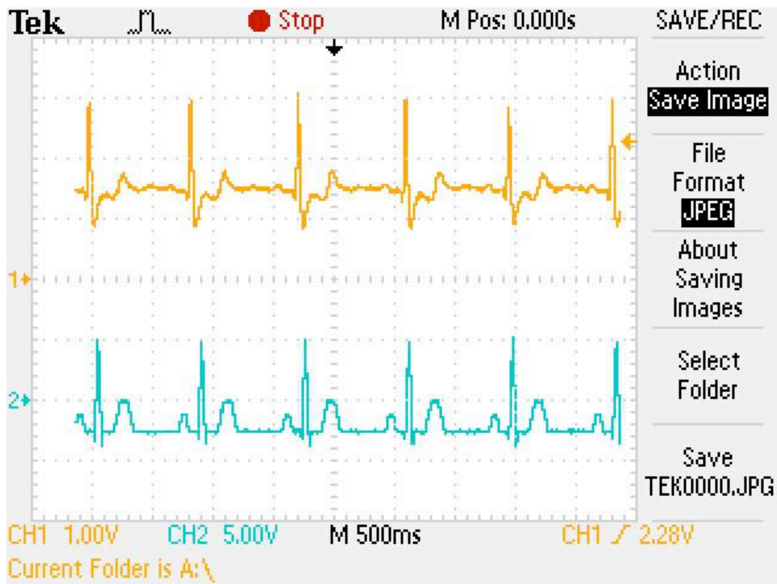
The system has been programmed to perform the following 10 functions.

Function 00
Binary counter



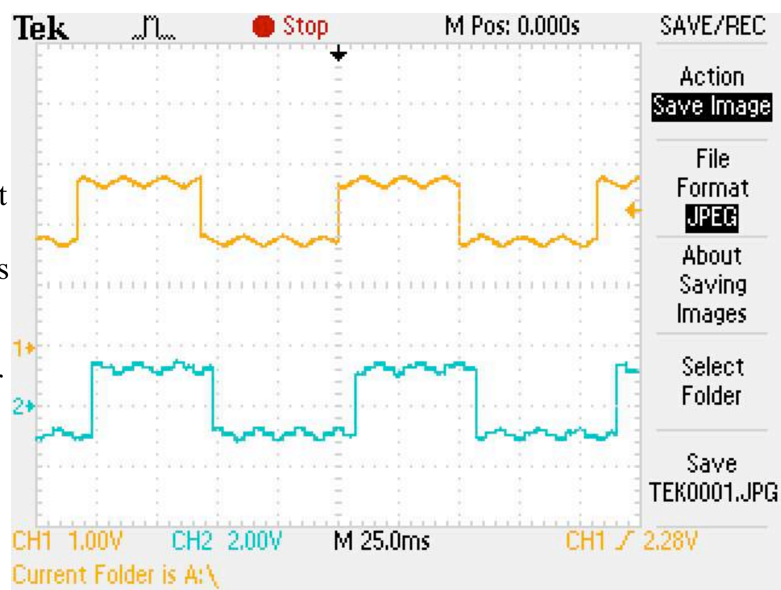
The binary count is displayed via the 4 LED's driven by RB4-RB7. The count is also sent to the D/A converter to generate a ramp signal. The ramp can be used to verify the linearity and offset of the D/A converter. The offset can be eliminated by adjusting Vref- (pin 12) of the DAC0800. Currently this voltage is set at 1.2 V with a voltage divider circuit (1.5 KΩ and 4.7 KΩ).

Function 01
ECG Simulation



Digitally simulated ECG is shown on channel 2 (cyan), compared to a real ECG waveform recorded from a human subject on channel 1 (orange). The timer TMR0 is set to generate interrupts at 1KHz, which provides a temporal resolution of 1 ms for the synthetic ECG waveform.

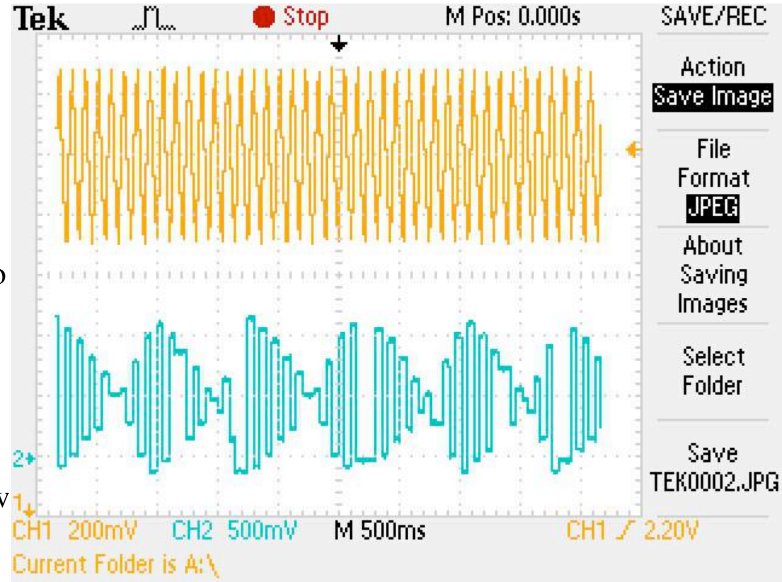
Function 02
Echo (A/D – D/A)

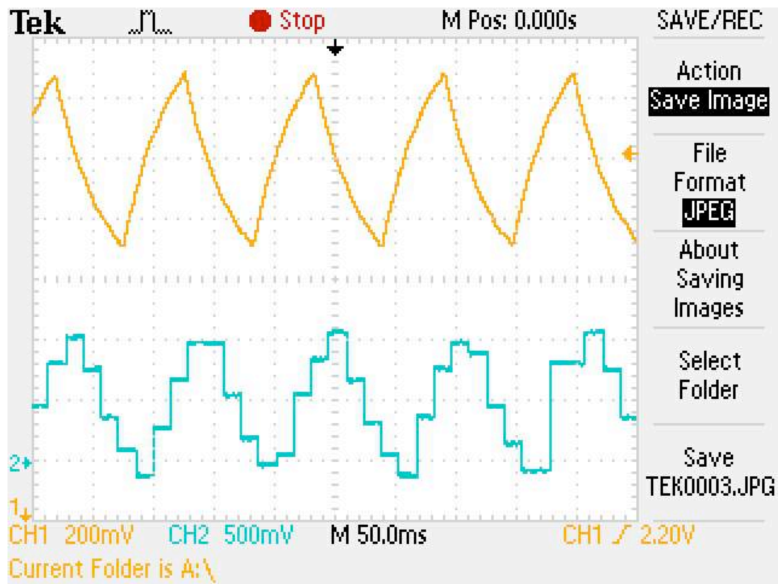


The analog signal channel 1 (orange) is from the on-board waveform generator that produces a 9-Hz square wave mixed with simulated 60 Hz noise. The analog signal is acquired by the on-chip D/A via channel AN0 (pin 2) at a sampling rate of 240 Hz and directly outputted to the D/A converter as shown on channel 2 (cyan).

Function 03
Echo @ fs 17 Hz

The sampling rate can be adjusted via the 100 KΩ potentiometer connected to AN2 (pin 4). A 47 µF capacitor is temporarily connected between AN0 (pin 2) and ground to change the square wave closer to a sine wave. A set of sampling rates ranging from 16 Hz to 228 Hz is programmed into the processor. The purpose is to observe the the effect of sampling rate. For example, aliasing is demonstrated in the right figure with a sampling rate of 17 Hz, which is just below the Nyquest sampling rate for the 9 Hz signal. The next figure shows the result with a sampling rate of 70 Hz.



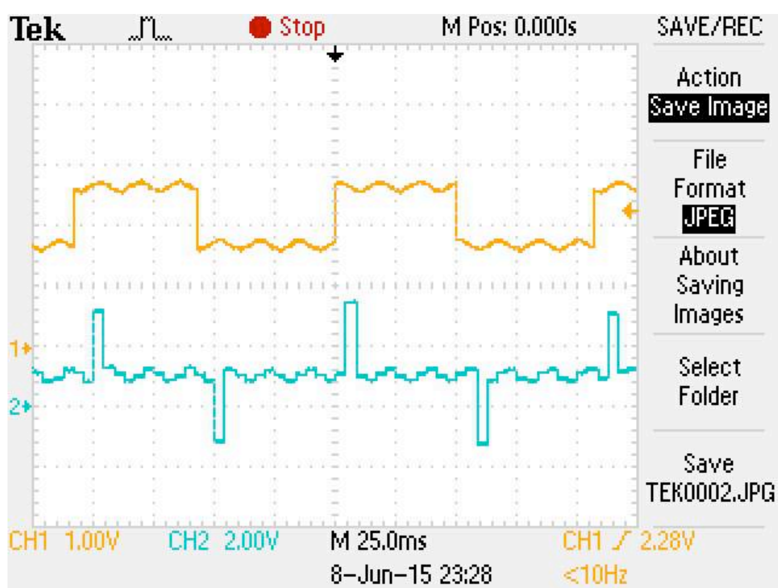


Function 04
Derivative

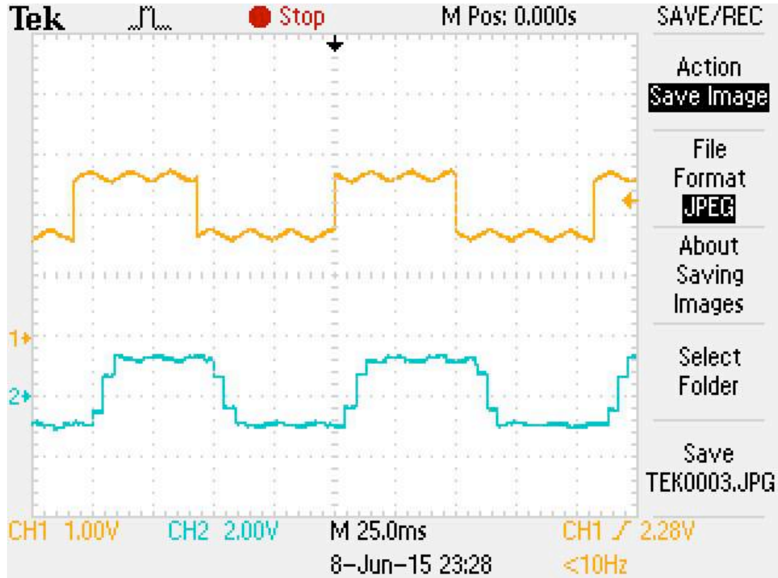
A digital differentiator is implemented according to the following backward difference:

```
y[n] = x[n] - x[n-1]
```

The sampling rate is 240 Hz.



Function 05
Low-pass filter

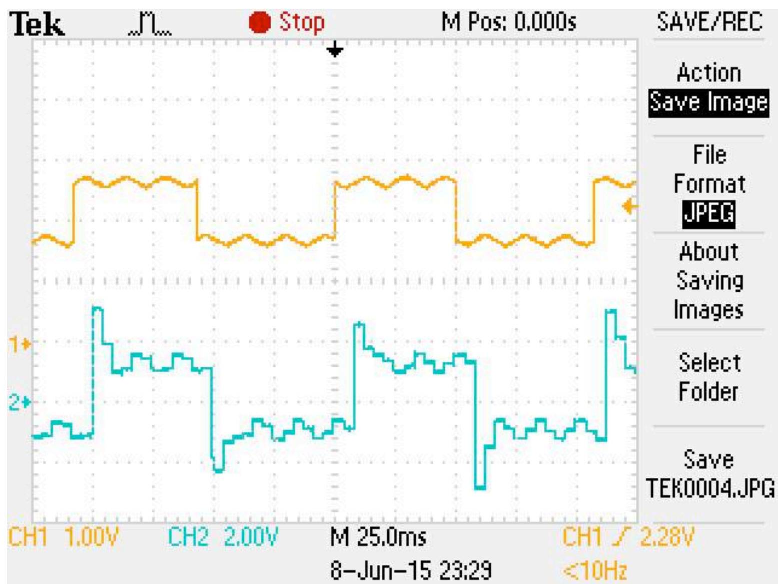


An FIR low-pass filter is implemented according to the following equation:

```
y[n] =
(x[n] + 2*x[n-1] + x[n-2) / 4
```

The sampling rate is 240 Hz.

Function 06
Hi-freq enhance

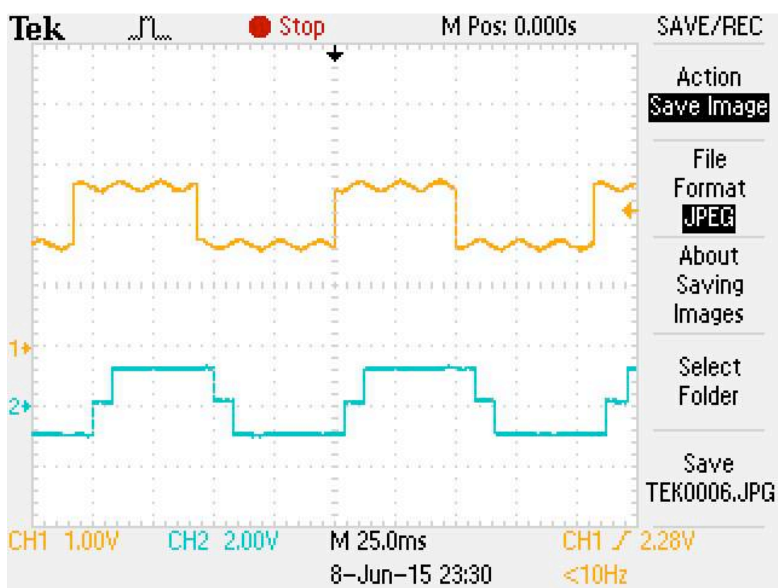


An FIR high-frequency enhancement filter is implemented according to the following equation:

```
y[n] = 2*x[n] -
(x[n] + 2*x[n-1] + x[n-2) / 4
```

The sampling rate is 240 Hz.

Function 07
60Hz notch filtr



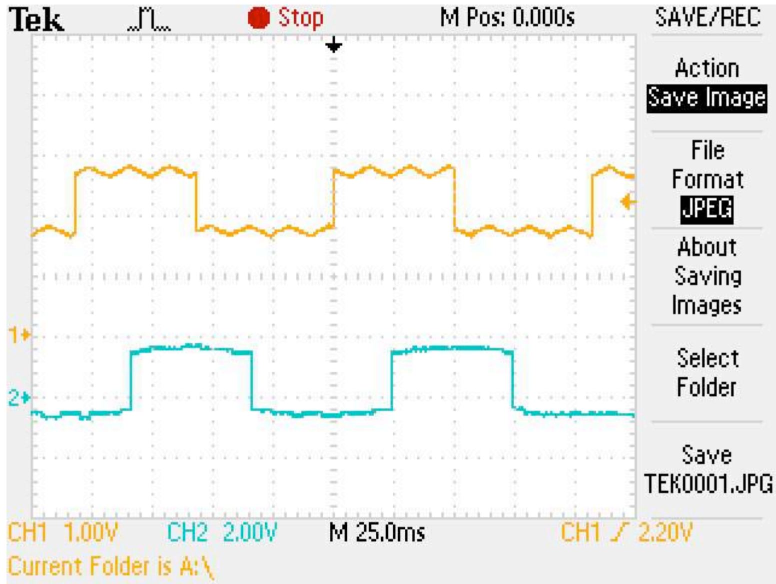
An FIR 60-Hz notch filter is implemented according to the following equation:

```
y[n] = (x[n] + x[n-2) / 2
```

The sampling rate is 240 Hz.

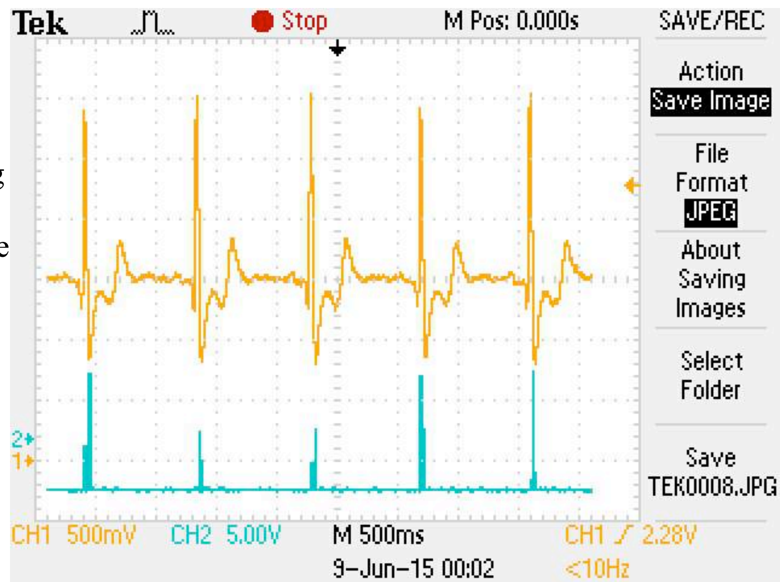
Function 08
Median filter

A median filter is implemented by performing a bubble sort of the present sample point and the past 8 sample points. The output is the median of the 9 points. The result in the figure shows the effect of edge-preserving smoothing of the median filter. The 60 Hz noise is eliminated, while the edges are preserved. The filter output shows a delay of 25 ms, which is longer than those of the previous filters.

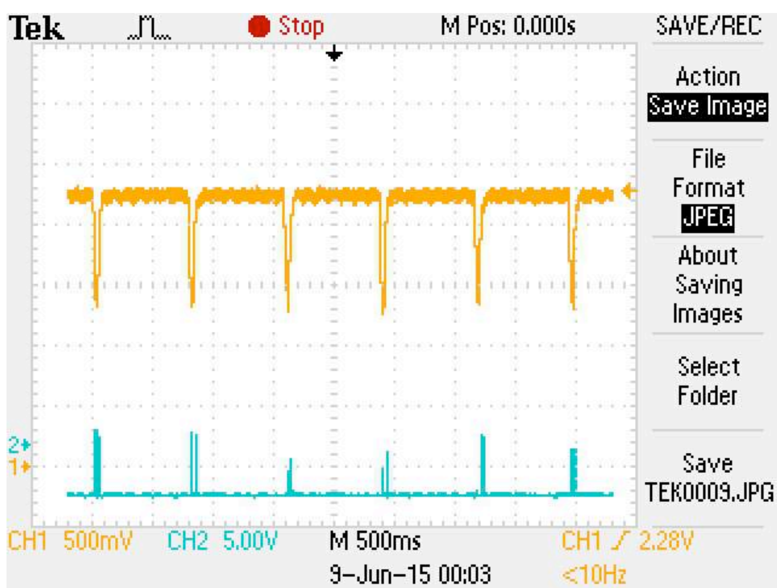


Function 09
HR: 74 bpm

A heart meter is implemented by executing the multiplication of backward differences (MOBD) algorithm for QRS detection. The sampling rate is set at 200 Hz. Figure on the right shows the ECG signal recorded from a human subject and the nonlinear transform of the MOBD algorithm. The MOBD algorithm significantly enhances the signal-to-noise ratio readily for the threshold detection. Except for the QRS complex other components such as the P wave, the T wave, and the noise are reduced to the baseline.



The next figure shows the analog simulated ECG and the MOBD nonlinear transform. The simulated ECG contains 60 Hz noise, which is effectively eliminated by the MOBD algorithm.



Bill of Materials

#	Description	Part number	Qty
1	Processor	PIC18F4525	1
2	D/A converter	DAC0800	1
3	Voltage regulator (5V, 1A)	LM7805	1
4	Voltage Inverter	LMC7660	2
5	Instrumentation amplifier	AD620	1
6	Dual timer	LM556	1
7	Timer	LM555	1
8	Quad op amp	LM324	1
9	NPN transistor	2N2222	1
10	Serial LCD display (16x2)	SerLCD	1
11	Buzzer	Mini buzzer (12V)	1
12	Ceramic resonator	4 MHz	1
13	LED	green	4
14		yellow	1
15	Resistor (x44)	220 Ω	1
16		330 Ω	2
17		470 Ω	5
18		1 KΩ	2
19		1.2 KΩ	1
20		1.5 KΩ	2
21		2.7 KΩ	1
22		3.3 KΩ	4
23		4.7 KΩ	2
24		10 KΩ	12
25		15 KΩ	1
26		22 KΩ	1
27		27 KΩ	2
28		47 KΩ	1
29		100 KΩ	3
30		330 KΩ	3
31		470 KΩ	1
32		1 MΩ	2
33	Potentiometer (x2)	1 KΩ	1
34		100 KΩ	1
35	Capacitor (x16)	.01 μF (103)	7
36		.1 μF (104)	1
37		.22 μF (224)	1
38		1 μF (electrolytic)	2
39		4.7 μF (electrolytic)	1
40		10 μF (electrolytic)	3
41		100 μF (electrolytic)	1
42		220 μF (electrolytic)	1
43	Switch	Momentary tact switch	2
44		Pushbutton on/off switch	1
45		SPDP slide switch	1
46	Power supply	9V battery or AC adapter	1