ELEC3730 Final Design Laboratory: General Lab Test Instrument (GLTI)

1 Overview

This final design laboratory concerns the implementation of a general laboratory test instrument (GLTI). This device will involve the generation and analysis of signals in a frequency range of 0-30kHz, and depending on student choice, may involve some or all of the following capabilities:

1. A menu system for controlling the GLTI which is implemented via the keypad and associated LCD display;
2. A 0-5V voltmeter;
3. A 0-X Khz (the number X will be defined later) function generator capable of the following function shapes with arbitrary fundamental frequency and amplitude, specified via keypad and LCD display:
   (a) Sine;
   (b) Square;
   (c) Triangle;
   (d) Sawtooth;
   (e) Reverse Sawtooth;
   (f) Random noise.
4. A 0-X kHz modulator, that can accept a modulating function input, and uses any of the above waveforms as the carrier to be modulated. This should involve a choice of
   (a) Amplitude Modulation;
   (b) Frequency Modulation.
5. A 0-X kHz frequency counter. That is, a device that displays the fundamental frequency of an incoming signal.
6. A tunable bandpass filter, with upper and lower cutoff frequencies specified in Hz via the keypad and LCD display.
7. Arbitrary function mapping from A/D input to D/A output. For example, output is four times input plus dc offset, specified as `4*x+2` via keypad and LCD display.

8. A demodulator, that can receive the above mentioned Amplitude and Frequency modulated signals and recover the modulating function.

9. A capacitance meter. This would involve driving a test voltage signal via a D/A converter across a capacitor/resistor pair, and determining the capacitance from a response observed via the A/D converter.

10. (Hard) Control of the GLTI via a PC over a serial link.

The challenge in this final design laboratory is to implement the above capabilities as an embedded application, running in "real time", on a development board employing the Mitusbishi M16C microcontroller.

This is a 16-bit microprocesser with 16MHz clock rate, and features 256k of internal flash RAM, 20k of internal RAM, and 87 programmable digital I/O lines. It also features on-chip programmable timers, serial I/O, A/D and D/A converters.

2 Design Specification - Basic

For a passing grade of 55% for a 2 person group, items 1-3 of the GLTI specification above at bandwidth $X = 1$ kHz must be demonstrated to be implemented correctly as an embedded application on a Mitsubishi M16C starter kit, and with user specified sampling frequency in the range $0 - 60$kHz. It is not necessary to use a real time operating system to achieve a passing grade in this category.

3 Design Specification - Extended

For a superior grade beyond 55% and up to 70% for a 2 person group, all of the above basic specifications must be met at bandwidth $X = 10$ kHz, together with 4-6 of the GLTI specification. It is not necessary to use a real time operating system to achieve a 70% grade in this category.

4 Design Specification - Advanced

For an excellent grade beyond 70% for a 2 person group, all the above basic and extended specifications must be achieved, together with further aspects such as

1. Bandwidth $X > 10$ kHz;

2. Organisation of background tasks via the μC/OS-II real time kernel which has been ported to the M16C microcontroller. This port may be downloaded via the ELEC3730 homepage;

3. Implementation of the remaining aspects of the GLTI specification above;

4. Implementation of further capabilities designed by the group members.

5 Laboratory Availability

This required development environment and Mitsubishi M16C boards will be available in laboratory EEG03. This laboratory is booked for the exclusive use of ELEC3710 students from 9am Monday until noon Wednesday of each week. To access this lab via your swipe card you need to have completed the safety induction and general access quizzes available via your blackboard login.

6 Assistance

Laboratory demonstrators will be available in EEG03 in order to answer questions or provide other assistance on Wednesdays between 12pm and 2pm.

7 Assessment

For this laboratory you are required to work in groups of two The final grade will be shared equally amongst the team members. You are free to choose whichever team members you wish. For the purposes of assessment, you will be required to perform the following:

1. Demonstrate your solution to a laboratory demonstrator;
2. Submit a listing of your solution together with a *brief* overview of its design and unique features. This overview should be no more than three pages.

Based on this submitted material and how well your final design performs when tested, a grade will be assigned.

8 Hardware and Development Tools Description

Complete documentation for the M16C microcontroller and SK2 starter kit including circuit diagrams, programming reference manuals, and tutorials for using the development environment are all available via the ELEC3730 homepage under the "Design Assignment" link.

9 Background Information

9.1 Sampling of signals

The GLTI in this document works with real time signals, which can be represented as a function of time, say $x(t)$. However, in order to work with these signals, the M16C must take "snapshots" of the signal at regular intervals.

The spacing between these intervals, denoted by Δ, and measured in seconds, is called the sampling period. On the M16C it is determined by setting an on-board clock. You will see examples of how to do this in the M16C tutorials provided in the "Tutorials" section of the ELEC3730 homepage.

Therefore, your GLTI cannot work with the whole real time signal $x(t)$, it can only work with the snapshots taken at the times

$$t = 0, \Delta, 2\Delta, 3\Delta, \cdots$$

That is, your GLTI only has available samples x_k defined as

$$x_k = x(t)|_{t=k\Delta} = x(k\Delta).$$

9.2 Modulation

Given samples x_k of a carrier to be modulated, and a signal y_k that specifies the modulation, then the modulated signal z_k is defined as

Amplitude Modulation

$$z_k = x_k \times y_k.$$

Frequency Modulation

$$z_k = x_n, \qquad n = \beta(x_k - \alpha)k$$

for some user chosen constants α, β. That is, the time scale (and hence underlying fundamental frequency) is either increased (when the input $x_k > \alpha$) or decreased (when the input $x_k < \alpha$) with proportionality constant β.

9.3 Tunable Filter

In order to implement a tunable bandpass filter which takes input samples u_k, and provides filtered output samples y_k, the following IIR filter can be used

$$y_k = -\frac{a_1}{a_2}y_{k-1} - \frac{a_0}{a_2}y_{k-1} + \frac{b_2}{a_2}u_k + \frac{b_1}{a_2}u_{k-1} + \frac{b_0}{a_2}u_{k-2}$$

where

$$a_2 = (\Delta\omega_u - 2)(\Delta\omega_\ell + 2) + 8, \quad a_1 = 2\omega_\ell\omega_u\Delta^2 - 8, \quad a_0 = (\Delta\omega_u + 2)(\Delta\omega_\ell - 2) + 8$$

and

$$b_2 = 2(\omega_u - \omega_\ell)\Delta, \quad b_1 = 0, \quad b_0 = -b_2$$

with $[\omega_\ell, \omega_u]$ specifying the frequency range (in radians per second) over which signals are passed, and Δ specifying the sampling frequency in seconds. Recall that cyclic frequency f is related to radian per second frequency ω by $\omega = 2\pi f$.

Port Allocations for MC16/LCD-kepad extension boards.

Function	Connector Pin		M16C Port
Keypad Column Scan		P2	
Col1	c11	-	P2_0
Col2	b11	-	P2_1
Col3	a11	-	P2_2
Col4	c12	-	P2_3
LCD Control			
Register Select	b12	-	P2_4
Read/Write	a12	-	P2_5
Enable	c13	-	P2_6
Digital Outputs			
CRO Trigger O/P	b13	-	P2_7
LCD Data		P3	
D0	a13	-	P3_0
D1	c14	-	P3_1
D2	b14	-	P3_2
D3	a14	-	P3_3
D4	c15	-	P3_4
D5	b15	-	P3_5
D6	a15	-	P3_6
D7	c16	-	P3_7
Analogue Outputs			P9
Spectrum Out	c31	-	P9_4/DA1
Analogue Inputs			P10
Analogue0	a2	-	P10_0/AN0
Analogue1	a3	-	P10_2/AN2
Keypad Row Scan			
Row1	b4	-	P10_4
Row2	a4	-	P10_5
Row3	c5	-	P10_6
Row4	b5	-	P10_7

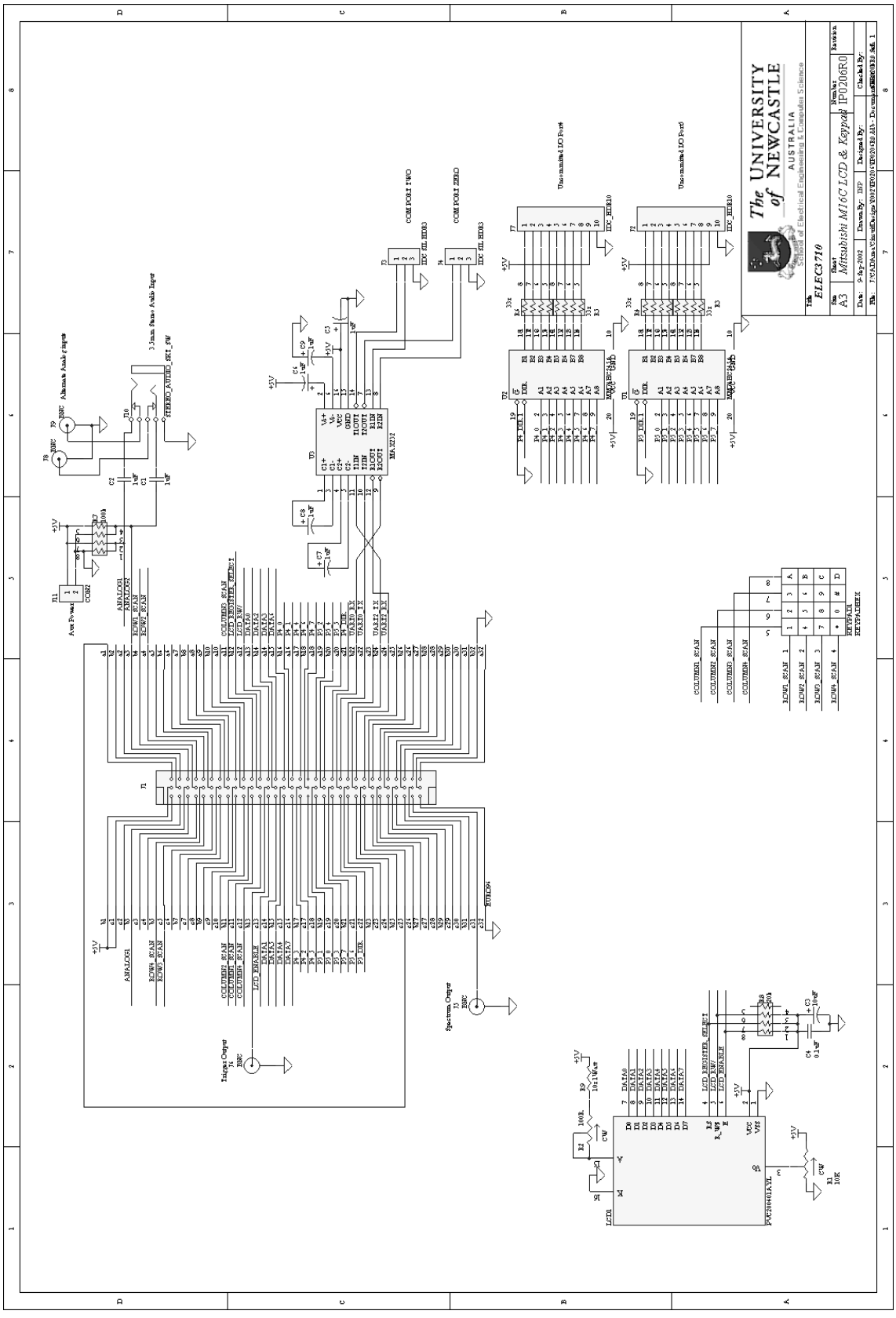

Figure 1: Mitsubishi MC16 Expansion Board