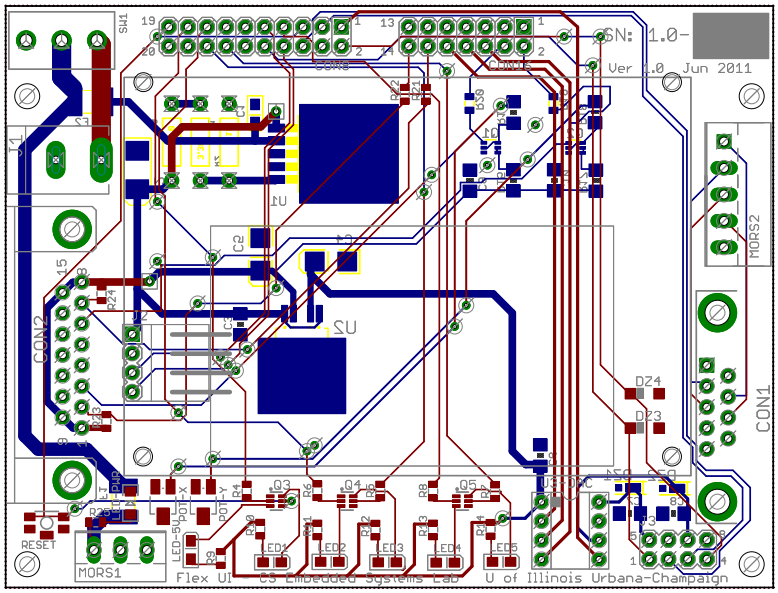

FLEX UI Circuit Board
TECHNICAL MANUAL

University of Illinois Urbana-Champaign
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Adapted for CS-454/654 at Boston University

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Table of Contents

1 Introduction

While the CS 454/654 Lab Manual provides a user guide on the FLEX Amazing Ball System and the FLEX UI Board, this manual provides more technical details of the FLEX UI Board. The details include concept of operation, testing, repairing, schematics, and bill of materials for the hardware subsystems.

As a review from the Lab Manual, the Amazing Ball System is a platform designed to give CS 454/654 students experience programming an actual embedded system. The system consists of three main circuit boards in a stacked configuration: FLEX Light Base Board, FLEX Demo2 Daughter Board, and our custom designed FLEX UI board. Each board extends the capability of the FLEX Light Base Board. At the core is a Microchip dsPIC33F digital signal microcontroller.

2 FLEX UI Board

The primary purpose of the FLEX UI board is provide an nice user interface to the system with standard connections for power, joystick gameport and RS232 (DE9) connection for serial communications. The FLEX UI Board adds the following additional features:

- 128x64 pixel monochrome Graphical LCD module.
- 2-channel 12-bit digital to analog converter (DAC) (5V operating range).
- Five software controllable green LEDs.
- Serial port (DE9 Connector).
- One analog joystick (DA15) connector and supporting hardware.
- Four general purpose input/output (GPIO) pins.
- Microcontroller reset button and associated red LED.
- Main power supply for the system with resettable fuse protection.

Some of these capabilities provide optional usage for CS 454/654 labs. With the exception of the DAC, all of these items will be described in further detail in subsequent sections of this manual. Details of the Microchip MCP4822 dual-voltage output DAC chip can be found in the manufacturer's datasheet, with a brief summary given in the CS 454/654 Lab Manual.

3 Power System

The FLEX-UI Board provides power to the whole system. This is done with a 12V, 2A AC/DC wall adapter that feeds into the 2.1mm power plug with a switch. The power is then provided to the FLEX Amazing Ball System and the FLEX UI Board through two separate resettable fuses. Each subsystem has their own 1A voltage regulators.

3.1 Resettable Fuses

Each of the resettable fuses have a Hold Current of 1.10A (normal operation) and a Trip Current of 1.95A. This means that if either of the subsystems draws more power than its normal operation, the fuse will eventually trip and shut-off the power to that subsystem. If this should occur, turn off the power and let the system cool down. The cooling resets the fuse. Before turning on the system make sure to look for possible causes such as a loose wire connection or a short (can be from a person touching the boards or static discharge).

3.2 Voltage Regulators

As mentioned before the FLEX Amazing Ball System and the FLEX UI Board both contain their own 1A voltage regulators. The FLEX Amazing Ball System is outside of the scope of this manual and will not be discussed. The FLEX UI Board's power is initially directed through a 6V, 1A voltage regulator which has a selectable voltage determined by the output resistors R1, R2 and R3. It is currently set to approximately 6V and provides the main power to the Graphic LCD screen (approximately 230mA at maximum backlight) and a smaller voltage regulator.

The subsequent voltage regulator is dual-channel and provides 3.3V to the analog Joystick hardware and 5V to the rest of the FLEX UI subsystem including the LEDs and DAC. The output channels can source up to 350mA and 430mA respectively. All voltage regulators and the DAC chip are protected by several appropriately sized capacitors which protect from power surges and also provide undisturbed power to the system should it temporarily dip below normal operating voltage.

The final item provided on the FLEX UI board is the reset button located at the lower left corner. When pressed, this grounds the MCLR signal of the dsPIC33 and resets the microcontroller only. The associated Red LED is an indicator of the reset condition.

For more details on the specific hardware used and their electrical characteristics, see the Bill of Materials in the Appendix and associated datasheets.

3.3 Power System Testing

Follow the below procedure to test or debug a power system issue:

1. Turn-on system, Check voltage at MORS1, pin 1 = 12V (leftmost pin)
2. Check voltage at J2 (LCD), pin 1 = approx 6V
3. Check voltage at U3-DAC, pin 1 = approx 5V
4. Check voltage at CON2 (DA-15), pins 1,8 = 3.3V (check both sides of R23, R24)
5. Check votlage at R9,R10,R11,R12,R13,R14 bottom terminal (LED side) = approx 5V.

4 Light Emitting Diodes (LEDs)

The FLEX UI Board has several LED configurations. The one Blue LED is connected directly to the 12V power supply. There are also five software controlled Green LEDs on the FLEX UI board and one Red LED that is associated with the MCLR (aka reset) line.

4.1 LED Power Supply

These are connected to three dual-channel MOSFET Transistors which switch on/off the LEDs. The LEDs and associated MOSFET transistors are powered from the dual channel voltage regulator at 5V. The primary reason for supplying LED power from the FLEX UI voltage regulator rather than directly from the microcontroller is so that the microcontroller's I/O pins never reach their absolute maximum output current. This can result in a microcontroller brown-out and cause unpredictable results or permanent damage.

4.2 Switching Control

The MOSFET gates are connected to several pins on the CON8 header (see the below table), and with the exception of the Red Reset LED all can be controlled by microcontroller software. For more wiring details see the FLEX UI schematic.

LED Name	FLEX UI CON8	dsPIC33F Port
LED-5V	Pin 5	MCLR
LED1	Pin 17	RA4
LED2	Pin 16	RA5
LED3	Pin 15	RA9
LED4	Pin 14	RA10
LED5	Pin 7	RA0

Table 1: LED Correlation Table

4.3 LED System Testing

Follow the below procedure to test or debug a LED issue. Please refer the FLEX UI Schematics while testing the LEDs:

1. Check LED-PWR works with Power Switch SW1.
2. Set an external DC power supply to 3V (***confirm the voltage with a multimeter).
3. Power-off the Flex-UI board and connect the GND of the power supply to MORS1 pin2 (middle pin).
4. Turn on DC power supply and Flex-UI board.
5. Check that LEDs work by applying 3V to CON8, pins 17,16,15,14,7,5.
6. LEDs 1,2,3,4,5 and LED-5V should activate with 3V on each pin.

5 Joystick Hardware System

The FLEX UI Board supports the use of older analog joysticks through the DA-15 Gameport connector. It is common for this size of port to be mistakenly called a DB-15 connector. Digital joysticks are not generally supported on this system.

5.1 Joystick Analog Axes

The older joysticks use non-linear joystick potentiometers to reflect the X and Y positions. In otherwords, the voltage reading of the X-axis might follow more of a logarithmic curve with the position of the Joystick. This makes fine-granularity control applications using non-linear joysticks very difficult. To compensate for the non-linearity older joystick interfaces also used a timer and capacitive discharge cycles to correctly sample the X and Y positions and read the rate of change of position. So non-linearity did not matter. Some joysticks solve the issue by using expensive linear potentiometers or by using Hall Effect joysticks (electromagnetic sensing) to sense the exact joystick position.

The FLEX UI Board implements an alternate, low-cost solution using constant current sources. Using Ohm's law where $V = IR$, if current I is constant then the voltage V becomes proportionate to the resistance R value ($V \propto R$). This means that the voltage response in the analog joystick now exhibits a linear relationship to the potentiometer's resistance value as determined by the X or Y axis position.

The two constant current sources (one for the X-axis and one for the Y-axis) are configured with opposing small signal NPN bipolar transistors (see the FLEX UI schematic for details). Each axis circuit also provides a calibration trim-potentiometer on the lower left side of the FLEX UI Board that will bias the voltage of the Joystick axis at center position. The calibration procedure sets these potentiometers such that approximately 1.65V is the center voltage (3.3V divided by 2).

The upper voltage response of the joystick hardware when the joystick is all the way to the left or up position will be around 3.3V as expected. In contrast, the lower voltage response when the joystick is all the way to the right or down position is around 0.6V rather than the expected 0V. This is because the Base-Emitter voltage of a BJT transistor must be approximately 0.6V before current can flow through the Collector-Emitter pins. Essentially this is the truncation of a full-range linear voltage response or a step-response. Students should keep this in mind when using the analog joystick hardware for system control applications.

5.2 Joystick Buttons

The joystick has two active buttons supported by the FLEX UI Board. The trigger is button #1 and the top thumb button is #2. The output pins are normally held at a high voltage (3.3V) by external pull-up resistors R23 and R24. When a button is pressed, its circuit gets shorted to ground with a resulting voltage response that goes from 3.3V down to approximately 160mV. This is a residual voltage from the large pullup resistor and a small trickle current.

Most microcontrollers interpret any voltage below 0.6V as digital logic 0. Therefore when joystick

button #1 is pressed the microcontroller interprets this as digital logic 0. Conversely if a button is not pressed the microcontroller interprets 3.3V as digital logic 1.

5.3 Joystick Power Supply

In normal Joystick interface design the supply voltage is typically at 5V to support TTL logic. The FLEX UI Board supplies the analog Joystick hardware with 3.3V which is the level required for the dsPIC33 I/O pins (3.6V max). If 5V were utilized, the dsPIC I/O port and ADC modules would experience high voltage and can create inaccurate ADC sensing characteristics (bleed-over into other ADC pins). Keep in mind that some older analog joysticks may not have the ability to operate at 3.3V and should be checked for compatibility using the subsequent test procedure.

5.4 Connection Pins

The Joystick X-axis, Y-axis, BTN1 and BTN2 are connected to several pins on the CON16 header (see the below table). Both the X and Y axes are connected to ADC inputs of the microcontroller, and BTN1 is connected to an external interrupt line. For more wiring details see the FLEX UI schematic.

Joystick Function	FLEX UI CON16	dsPIC33F Port
Y-axis	Pin 2	AN5
X-axis	Pin 2	AN5
BTN2	Pin 12	RD10
BTN1	Pin 14	INT1/RE8

Table 2: Joystick Correlation Table

5.5 Joystick Hardware Testing & Calibration

Follow the below procedure to test or debug a Joystick issue. Please refer the FLEX UI Schematics while testing the Joystick hardware:

1. Power-off system, Connect Joystick to DA-15 connector (CON2)
2. Turn-on system, Check voltage (CON16 pins 2,4) and adjust POT-X,POT-Y for voltage around 1.65 volts when Joystick is in center position.
3. Check X,Y axis voltage response for full swing (approx 3.3V and down to 0.6V depending on joystick).
4. Check BTN voltage response = 160mV when BTN is pressed (CON12 pins 12,14) *** *** If the joystick is equipped, Rapid fire should be turned off.

6 Graphical LCD

6.1 Overview of LCD Module

The LCD module is a Sparkfun LCD-09351 product comprising of an Amotec ADM12864H LCD screen (128x64 pixels) that is controlled by Sparkfun's Serial LCD Backpack. The LCD Backpack uses an Atmel ATmega128 microcontroller that enables a simple serial interface (Tx and Rx only) and is connected to the parallel data and control lines of the ADM12864H screen. The original firmware on this module has been overwritten by an open source firmware that is much more efficient and supports ASCII carriage returns and line feed characters.

The LCD Screen is connected to UART1 of the dsPIC33F and is supplied with by the FLEX UI Board's 6V voltage regulator. Using the LCD for text output is relatively straightforward and is described in the CS 454/654 Lab Manual using a C library that support the firmware's command set.

A special note should be taken that there are several commands in the LCD Backpack firmware that change default settings stored in non-volatile memory (retained when powered-off). This includes the backlight intensity, pixel polarity, and line feed with an ASCII carriage return character. It is possible for students to inadvertently use these commands. Subsequently the FLEX UI Test Software provides a calibration mode for the CS 454/654 TF(s) to quickly change these default settings. See section 6.3 for more details on the calibration mode.

6.2 LCD Testing

Follow the below procedure to test or debug a LCD issue. Please refer to the LCD datasheet and C library for more details:

1. Power-off system, Connect LCD to J2 (if not already connected)
2. Power-on System, Check for LCD Sparkfun Splash screen.
3. Check that LCD is displaying without any faded lines or blocks.
4. Check that LCD does not appear to have a contrast in the background. ***
5. Anchor LCD to FLEX UI PCB (if not already connected). Use #2 screws, nylon standoffs, and nylon locknuts (Hand tighten).

*** Contrast is factory set by potentiometer on LCD control board, do not usually need change the setting. (clockwise = less; counterclockwise = more) Should be set to the 9 o'clock position if the board edge and POT are facing away from you.

6.3 LCD Calibration Mode

This section describes how to use the FLEX UI Test Software to calibrates default LCD Screen Polarity, Backlight Intensity and CR Line Feed.

1. Connect to system with terminal emulator, view data in ASCII.
2. Turn on power switch (Flex UI board) with Joystick and RS232 cable attached.

3. Type "CAL" (uppercase) in the terminal emulator.
4. You will see the below displayed in the terminal emulator and LCD screen.
5. Follow the instructions in the terminal emulator to set the defualts values for Screen Polarity, Backlight Intensity and CR Line Feed which are stored in the LCD's non-volatile memory.

```
*********************************
LCD CALIBRATION MODE\\
*********************************

Press Joystick BTN2 (thumb) to toggle LCD Screen Polarity.
Press ENTER on the keyboard when DONE.

Press Joystick BTN2 (thumb) to toggle Backlight Intensity.
Press ENTER on the keyboard when DONE.

Press Joystick BTN2 (thumb) to toggle CR Line Feed.
Press ENTER on the keyboard when DONE.

LCD CALIBRATION DONE
*********************************
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7 Digital Interface and Software Control

7.1 Overview of Digital Interfaces

The FLEX UI board extends 4 digital interfaces from the Microchip dsPIC33F microcontroller:

1. Serial UART1 to the Graphical LCD Screen.
2. Five GPIO pins to the Green LEDs.
3. Four GPIO pins to Connector J3 (pins 1 to 4).
4. Serial Peripheral Interface (SPI) to the MCP4822 dual-voltage output DAC chip (U3).

Each of these interfaces are configured in the dsPIC33F software and controlled in different ways as described in the CS 454/654 Lab Manual. With regard to this Technical Manual, each digital interface is fully tested using the FLEX UI Test Software as described in section 7.2 Digital Interface & Software Testing.

It should be noted that all interfaces use MOS transistor technologies and are extremely susceptible to power spikes, electrostatic discharge (ESD), and other electrical faults. Simply put, permanent damage can be easily caused by the human touch. When servicing the system, please take the appropriate care in using a grounding strap and standard circuit board handling procedures (i.e. handling only by the edges).

It should also be noted that any pin which is multiplexed with the microcontroller's Analog-to-Digital Conversion (ADC) module, labeled with the prefix "AN", requires special software configuration before it can be used with the FLEX UI interfaces. See the CS 454/654 Lab Manual and the FLEX UI Test Software source code for more details. In addition, read and write operations to any of the microcontrollers I/O pins require a $Nop()$ between each operation. Finally some of the microcontroller's pins are capable of handling 5V, while others can only hand 3.3V. The FLEX UI Board utilizes Zener Diodes to prevent over voltage on these pins.

The Appendix includes more details of the multiplexed pin operations (FLEX UI Pinouts) and the wiring schematics.

7.2 Digital Interface & Software Testing

Follow the below procedure using the FLEX UI Test Software to ensure all digital interfaces are working correctly:

1. Turn on power switch (Flex UI board)
2. Verfiy that Evidence PID controll software is working (verifies that touchscreen works).
3. Program the Flex platform and dsPIC33F with the FLEX UI Board Test Software.
4. All 5 LEDs should illuminate.
5. DAC output on J3 should be approx 4.095V (pin 5) and 2.095 (pin 7).
6. GPIO Pins should be active with LEDs on (2.8V pins 1,4) and (3.1V pins 2,3). GPIO pins 1 and 4 were configured in software as digital for ADC1 and ADC2 otherwise they would not work as expected for GPIO.
7. Joystick BTN1 should toggle the lights and GPIO voltage outputs.

8. BTN2 changes the LCD display between 3 different states. BTN2 is debounced with schmitt trigger transistors and is sampled at a slower speed. Hold BTN2 until the desired LCD display state appears:

LCD State	Display Mode
1	Hello from Flex UI (*Default*)
2	Backlight Demo
3	Graphics Demo
***	Calibration Mode

9. Connect to system with terminal emulator (9600 baud, 8 data bits, 1 stop, no parity). View data in ASCII.
10. Serial Joystick data should change with Joystick movement (both axis) and with both BTN presses.

*** Calibration mode is accessible only through the dsPIC33F UART2 connection when uppercase "CAL" is typed. See section 6.3 for more details on the calibration mode.

8 System Repair and Component Replacement

8.1 General Notes

After thorough system testing has diagnosed an issue and has narrowed the root cause to a specific hardware component you must carefully decide whether to repair the component or replace the whole FLEX UI board. Replacement of the LCD screen or the DAC chip is easily performed with minimal tools and effort. Replacement or repair of the surface mount components is much more difficult, especially without a practiced individual performing the work.

The most important concept is to make sure you have the right tools, right temperatures, and right metal alloy before performing any repair. In particular there are several screw terminals on the FLEX system and the FLEX UI Board. Do not try to fit a larger screw driver in the hole.

8.2 Soldering

Special care must be taking if replacing any component that requires soldering/desoldering. Other than FLEX UI Serial No. 1.0-1 (which uses leaded solder), all FLEX UI boards meet RoHS standards with lead free solder. Yet they use two alloys that have very different melting temperatures. This means that you must be vary careful not to heat beyond the region of repair beyond above the lowest melting temperatures otherwise other components may shift or simply fall off. In addition, you should not mix the solder alloys during repair.

It is recommended to use a circuit board preheater to 125°C and hot air rework techniques to reduce impact on other components. Most components adhere to the the Joint Industry Standard J-STD-020 (available online) which classifies them to withstand 217°C for 60-150 seconds. Please check the component datasheets to verify the soldering/reflow temperature tolerances before performing any repair. Below is a list of the solder alloys used and their melting temperatures:

Location	Solder Alloy	Melting Temperature	Hazard
FLEX UI Serial No. 1	Sn62/Pb36/Ag2 Wire	183°C	Lead
Through-hole Components	Sn96.5/Ag3.0/Cu0.5 Wire	210°C	RoHS Lead-Free
Surface Mount Components	Sn42/Bi58 Reflow Paste	138°C	RoHS Lead-Free

Table 3: Solder Alloys Used on FLEX UI Board

8.3 Electrostatic Discharge (ESD) Caution

Remember that many components on the FLEX UI Board use MOS transistor technologies and are extremely susceptible to power spikes, electrostatic discharge (ESD), and other electrical faults. Simply put, permanent damage can be easily caused by the human touch. When servicing the system, please take the appropriate care in using a grounding strap and standard circuit board handling procedures (i.e. handling only by the edges).

8.4 System Assembly Procedure For FLEX UI Circuit Board Using Reflow (*For Reference Only*)

This section has been provided as a reference only. They may not necessarily apply to the desired repairs, but might provide some background information.

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REFLOW SETTINGS:
-----------------
A) X-Tronic 8040 Preheater:
-225 deg C (measures 135 C on bottom and 110 C on top)
B) Aoyue 986 Hot Air:
-3rd smallest round tip
-222 deg C (measures 165 C about 8mm away from tip, steady temp after heatup)
-Airflow set to 2.0
-----------------
1) Solder paste on cold PCB (not too much)
2) Place all components (close alignment, does not need to be exact)
3) Preheat PCB for 3:30 minutes
4) Preheat Hot Air for 1 minute
5) Reflow components making sure surface tension aligns components.  Have a pick
   ready to assist


=======================
ASSEMBLY ORDER
----------------
1) Reflow Bottom (let cool down to room temp)
2) Reflow Top
3) VISUAL INSPECTION OF REFLOW, fix or clean solder bridges.
4) Solder J1 (Power connector)**
5) Solder J2 (LCD connector)
6) Solder MORS2 (UART 5 pin)
7) Flip PBC and Solder U3 (DAC Socket), J3 (GPIO pins)
8) Solder CON2 (DA-15), CON1 (DE-9)
9) Solder CON16
10) Solder CON8
11) Solder MORS1, SW1 (Power SW)
12) Solder R1,R2,R3 power resistors **
** Make sure that top and bottom sides are soldered


=======================
VISUAL INSPECTION \& CLEANING
----------------
1) PCBs must be cooled down to room temperature
2) Make sure that top and bottom sides of PTH parts are soldered
3) Re-inspect Reflow for connections and solder bridges
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4) Drop Isopropyl Alcohol on small area and rub with brush. Clean whole PCB, both sides.
5) Rinse PCB with distilled water.
6) Let PCB air dry (although may use Reflow Preheater at 140 deg C to accelerate drying)

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AMAZING BALL SYSTEM ASSEMBLY
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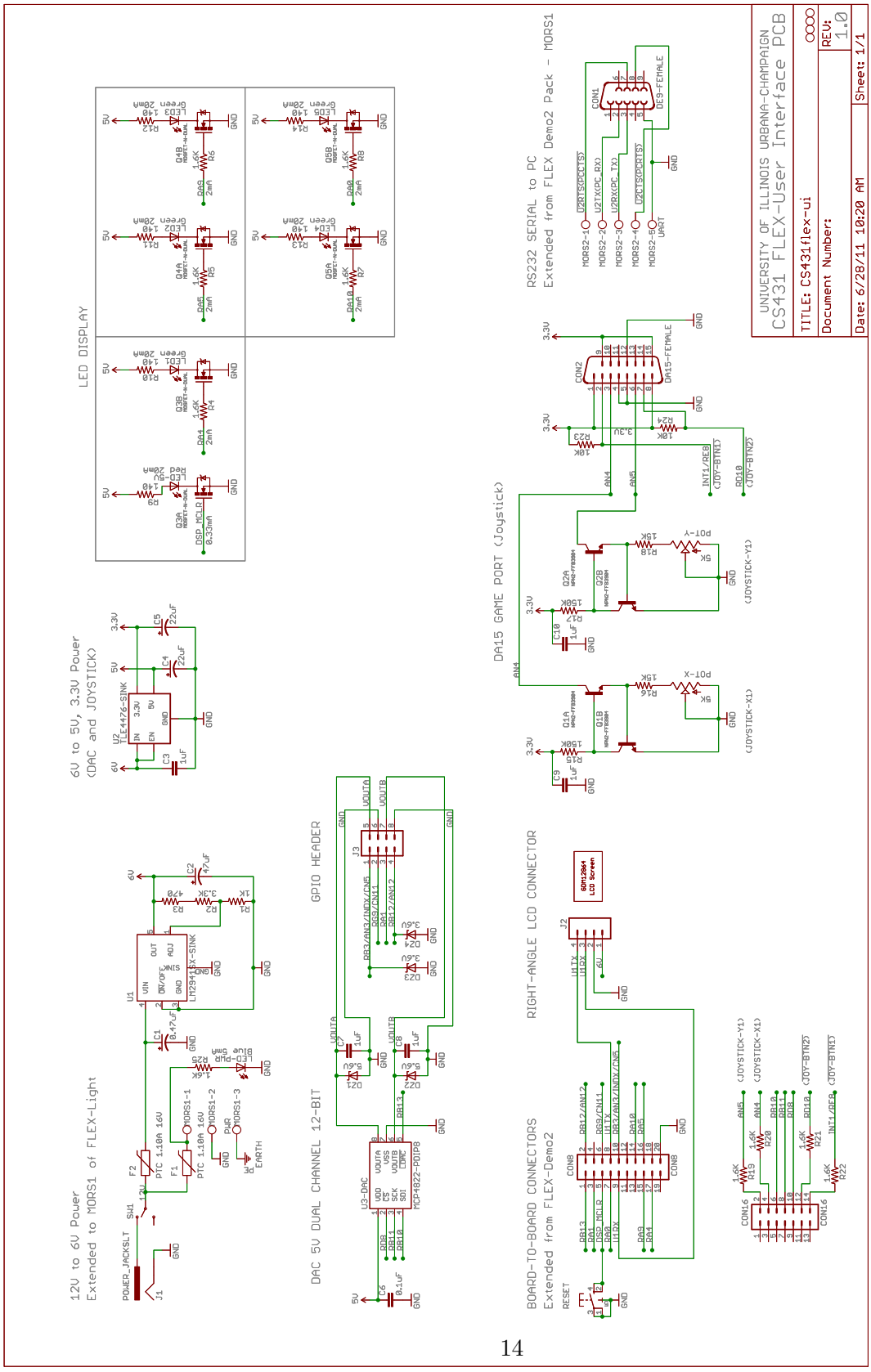
1) Install the Flex Light Base board onto the Amazing Ball platform.
2) Replace metric standoff on Flex Daughter board and Motor Board, with our 4-40 female-female 1/2" standoff, nylon screw, and 4-40 male-female 7/16" standoff.
3) Screw in 3 qty 1-1/4 standoffs to the Flex Daughter Board.
4) Place Touch screen and Servo cables onto Flex Daughter Board.
5) Place Daughter assembly on to Flex Base board.
6) Install Ribbon Cables (CON8, CON16) to Flex Daughter Board with the red stripe on the left side. CON16 may be slightly tilted given the tight fit - this is OK as long as the pins make firm contact.
7) Screw in UART wires to FLEX UI board.
8) Place FLEX UI board ontop of Flex Daughter standoffs and trim UART wires to the appropriate length.
9) Holding FLEX UI board on its side, screw in UART wires to Daughter Board.
10) Carefully place FLEX UI board on top of daughterboard and anchor to standoffs with 2 opposing screws (Lower Left, Upper Right). Do not tighten the screws
11) Place 2 nylon washers under the Upper Left screw hole of the FLEX UI board and anchor in place with a 4-40 screw.
12) Tighten all four of the FLEX UI screws.
13) Trim and insert the power wires to the FLEX UI board MORS1 (PWR, GND only).
14) Screw in Power wires to MORS1 Flex base board (Red and Black).
15) Insert Ribbon cables to FLEX UI board.

9 Appendix

9.1 FLEX-UI Schematic



9.2 FLEX-UI Pinouts

Pins Extended from FLEX Demo Daughter Board

Connector	DEMO Pin	dsPIC33F Pin	Description of Ports	Custom PCB Use	Other Notes
CON7 – UART to output DB9	1	-	CTS(232),CTS(TTL),NC(485),TX+(422)	UART_CTS – U2CTS#	PIN40 with UART support hardware
CON7 – UART to output DB9	2	-	RX(232),RX(TTL),485-,TX-(422)	UART_RX – U2RX	PIN49 with UART support hardware
CON7 – UART to output DB9	3	-	TX(232),TX(TTL),485+,RX+(422)	UART_TX – U2TX	PIN50 with UART support hardware
CON7 – UART to output DB9	4	-	RTS(232),RTS(TTL),NC(485),RX-(422)	UART_RTS – U2RTS#	PIN39 with UART support hardware
CON7 – UART to output DB9	5	-	GND	UART_GND	
CON8 – AUX Connector	1	PIN42	RB13/AN13	DAC_LDAC - RB13	
CON8 – AUX Connector	2	PIN41	RB12/AN12	GPIO – RB12/AN12	Can be used as ADC port for loopback
CON8 – AUX Connector	3	PIN38	RA1/TCK	GPIO - RA1	
CON8 – AUX Connector	4	PIN47	RD14/IC7/U1CTS#/CN20	--	Same as CON3-3
CON8 – AUX Connector	5	PIN13	MCLR#	Soft Reset PushBtn	
CON8 – AUX Connector	6	PIN14	RG9/SS2#/CN11	GPIO - RG9	
CON8 – AUX Connector	7	PIN17	RA0/TMS	LED5 – RA0	
CON8 – AUX Connector	8	PIN51	RF3/U1TX	LCD_TX - U1TX	Sparkfun Serial Graphic LCD (09351)
CON8 – AUX Connector	9	PIN52	RF2/U1RX	LCD_RX – U1RX	Sparkfun Serial Graphic LCD (09351)
CON8 – AUX Connector	10	PIN22	RB3/AN3/INDX/CN5	GPIO – RB3/AN3/INDX/CN5	Can be used as ADC port for loopback
CON8 – AUX Connector	11	PIN74	RC14/PGEC2/EMUC2/SOSCO/T1CK/CN0	--	Jumper JP16 to XT1
CON8 – AUX Connector	13	-	+AVDD_EXT	--	Jumper JP6 to PIN30 +AVDD
CON8 – AUX Connector	14	PIN29	RA10/VREF+	LED4 – RA10	
CON8 – AUX Connector	15	PIN28	RA9/VREF-	LED3 – RA9	
CON8 – AUX Connector	16	PIN61	RA5/TDO	LED2 – RA5	
CON8 – AUX Connector	17	PIN60	RA4/TDI	LED1 – RA4	
CON8 – AUX Connector	18	-	+5V	--	
CON8 – AUX Connector	19	-	+3.3V	--	
CON8 – AUX Connector	20	-	GND	GND – Digital	
CON16 – DC Motor 1 Connector	2	PIN20	RB5/AN5/QEB/CN7	Joystick AY -AN5(ADC2)	Game Port Pin6, +3.3V (LDO-VREG)
CON16 – DC Motor 1 Connector	4	PIN21	RB4/AN4/QEA/CN6	Joystick AX -AN4(ADC2)	Game Port Pin3, +3.3V (LDO-VREG)
CON16 – DC Motor 1 Connector	6	PIN34	RB10/AN10	DAC_SDI – RB10	
CON16 – DC Motor 1 Connector	8	PIN35	RB11/AN11	DAC_SCK – RB11	
CON16 – DC Motor 1 Connector	10	PIN68	RD8/IC1	DAC_CS – RD8	
CON16 – DC Motor 1 Connector	12	PIN70	RD10/IC3	Joystick A2 -RD10	Game Port Pin7, +3.3V (LDO-VREG)
CON16 – DC Motor 1 Connector	14	PIN18	RE8/AN20/FLTA#/INT1	Joystick A1 -INT1/RE8	Game Port Pin2, +3.3V (LDO-VREG)
CON16 – DC Motor 1 Connector	16	PIN19	RE9/AN21/FLTB#/INT2	--	

9.3 FLEX-UI Bill of Materials (BOM)

Bill of Materials Needed to build 1qty CS431 FlexUI Board:

Part	Module	Value	Supplier Part Number	Description	Supplier	Mfg Part Number
C1	PWR-6V	0.47uF	478-3964-1-ND	CAP TANTALUM .47UF 20V 10% SMD	Digikey	TAJR474K020RNJ
C2	PWR-6V	47uF	478-1718-1-ND	CAP TANTALUM 47UF 16V 10% SMD	Digikey	TAJC476K016RNJ
C3	PWR-5V/3.3V	1uF	478-1567-1-ND	CAP CERM 1UF 10% 25V X7R 1206	Digikey	12063C105KAT2A
C4	PWR-5V/3.3V	22uF	478-1683-1-ND	CAP TANTALUM 22UF 20V 10% SMD	Digikey	TAJB226K020RNJ
C5	PWR-5V/3.3V	22uF	478-1683-1-ND	CAP TANTALUM 22UF 20V 10% SMD	Digikey	TAJB226K020RNJ
C6	DAC	0.1uF	478-1556-1-ND	CAP CERM .1UF 10% 50V X7R 1206	Digikey	12065C104KAT2A
C7	DAC	1uF	478-1567-1-ND	CAP CERM 1UF 10% 25V X7R 1206	Digikey	12063C105KAT2A
C8	DAC	1uF	478-1567-1-ND	CAP CERM 1UF 10% 25V X7R 1206	Digikey	12063C105KAT2A
C9	JOYSTK	1uF	478-1567-1-ND	CAP CERM 1UF 10% 25V X7R 1206	Digikey	12063C105KAT2A
C10	JOYSTK	1uF	478-1567-1-ND	CAP CERM 1UF 10% 25V X7R 1206	Digikey	12063C105KAT2A
CON1	UART	DE9-FEMALE	A32117-ND	DE9 Female, CONN D-SUB RCPT R/A 9POS 30GOLD	Digikey	AMP 5747844-4
CON2	JOYSTK	DA15-FEMALE	5788798-1-ND	DA-15 Female, CONN D-SUB RCPT 15POS R/A GOLD	Digikey	AMP 5788798-1
CON8	BOARD	CON8	S2011E-36-ND	CONN HEADER .100 DUAL STR 72POS	Digikey	PBC36DAAN
CON16	BOARD	CON16	S2011E-36-ND	CONN HEADER .100 DUAL STR 72POS	Digikey	PBC36DAAN
DZ1	DAC	5.6V	PD3Z284C5V6DICT-ND	DIODE ZENER 5.6V 500MW PWRDI-323	Digikey	PD3Z284C5V6-7
DZ2	DAC	5.6V	PD3Z284C5V6DICT-ND	DIODE ZENER 5.6V 500MW PWRDI-323	Digikey	PD3Z284C5V6-7
DZ3	GPIO	3.6V	MMSZ5227B-FDICT-ND	DIODE ZENER 3.6V 500MW SOD-123	Digikey	MMSZ5227B-7-F
DZ4	GPIO	3.6V	MMSZ5227B-FDICT-ND	DIODE ZENER 3.6V 500MW SOD-123	Digikey	MMSZ5227B-7-F
F1	PWR	PTC 1.10A 16V	507-1500-1-ND	PTC RESTTBLE 1.10A 16V CHIP 1812	Digikey	0ZCC0110AF2C
F2	PWR	PTC 1.10A 16V	507-1500-1-ND	PTC RESTTBLE 1.10A 16V CHIP 1812	Digikey	0ZCC0110AF2C
J1	PWR	POWER_JACKSLT	CP-037AH-ND	CON PWR JCK 2.0 X 6.5MM HIGH CUR	Digikey	PJ-037AH
J2	LCD		S5479-ND	CONN FEMALE 4POS .100" R/A GOLD	Digikey	PPPC041LGBN-RC
J3	GPIO/DAC		S2011E-36-ND	CONN HEADER .100 DUAL STR 72POS	Digikey	PBC36DAAN
LED-5V	LED	Red 20mA	67-1356-1-ND	LED 635NM RED WTR CLR 1206 SMD, 2V, 20mA	Digikey	SML-LX1206IC-TR
LED-PWR	PWR	Blue 5mA	P11525CT-ND	LED BLUE (UP) W/LENS 1206, 5mA, 3V	Digikey	LNJ916C8BRA
LED1	LED	Green 20mA	67-1357-1-ND	LED 565NM WTR CLR GREEN 1206 SMD, 2.2V, 20mA	Digikey	SML-LX1206GC-TR
LED2	LED	Green 20mA	67-1357-1-ND	LED 565NM WTR CLR GREEN 1206 SMD, 2.2V, 20mA	Digikey	SML-LX1206GC-TR
LED3	LED	Green 20mA	67-1357-1-ND	LED 565NM WTR CLR GREEN 1206 SMD, 2.2V, 20mA	Digikey	SML-LX1206GC-TR
LED4	LED	Green 20mA	67-1357-1-ND	LED 565NM WTR CLR GREEN 1206 SMD, 2.2V, 20mA	Digikey	SML-LX1206GC-TR
LED5	LED	Green 20mA	67-1357-1-ND	LED 565NM WTR CLR GREEN 1206 SMD, 2.2V, 20mA	Digikey	SML-LX1206GC-TR
MORS1	PWR	PWR	ED1515-ND	TERMINAL BLOCK 3.5MM 3POS PCB	Digikey	ED555/3DS
MORS2	UART	UART	ED1504-ND	TERMINAL BLOCK 3.5MM 5POS PCB	Digikey	ED550/5DS
POT-X	JOYSTK	5K	ST32ETB502CT-ND	POT 5.0K OHM 3MM CERM SQ TOP SMD	Digikey	ST32ETB502
POT-Y	JOYSTK	5K	ST32ETB502CT-ND	POT 5.0K OHM 3MM CERM SQ TOP SMD	Digikey	ST32ETB502
Q1	JOYSTK	NPN2-FFB3904	FFB3904CT-ND	TRANSISTOR NPN 40V SC70-6	Digikey	FFB3904
Q2	JOYSTK	NPN2-FFB3904	FFB3904CT-ND	TRANSISTOR NPN 40V SC70-6	Digikey	FFB3904
Q3	LED	MOSFET-N-DUAL	DMN66D0LDWDICT-ND	MOSFET N-CH DUAL 115MA SOT-363	Digikey	DMN66D0LDW-7
Q4	LED	MOSFET-N-DUAL	DMN66D0LDWDICT-ND	MOSFET N-CH DUAL 115MA SOT-363	Digikey	DMN66D0LDW-7
Q5	LED	MOSFET-N-DUAL	DMN66D0LDWDICT-ND	MOSFET N-CH DUAL 115MA SOT-363	Digikey	DMN66D0LDW-7
R1	PWR-6V	1K	1KADCT-ND	RES 1K OHM 1/4W 0.1% MF AXL	Digikey	MFP-25BRD52-1K
R2	PWR-6V	3.3K	3.3KADCT-ND	RES 3.3K OHM 1/4W 0.1% MF AXL	Digikey	MFP-25BRD52-3K3
R3	PWR-6V	470	470ADCT-ND	RES 470 OHM 1/4W 0.1% MF AXL	Digikey	MFP-25BRD52-470R
R4	LED	1.6K	RHM1.60KCCT-ND	RES 1.60K OHM 1/8W 1% 0805 SMD	Digikey	MCR10EZHF1601
R5	LED	1.6K	RHM1.60KCCT-ND	RES 1.60K OHM 1/8W 1% 0805 SMD	Digikey	MCR10EZHF1601
R6	LED	1.6K	RHM1.60KCCT-ND	RES 1.60K OHM 1/8W 1% 0805 SMD	Digikey	MCR10EZHF1601
R7	LED	1.6K	RHM1.60KCCT-ND	RES 1.60K OHM 1/8W 1% 0805 SMD	Digikey	MCR10EZHF1601
R8	LED	1.6K	RHM1.60KCCT-ND	RES 1.60K OHM 1/8W 1% 0805 SMD	Digikey	MCR10EZHF1601
R9	LED	140	RHM140HCT-ND	RES 140 OHM 1/10W 1% 0603 SMD	Digikey	MCR03EZPFX1400
R10	LED	140	RHM140HCT-ND	RES 140 OHM 1/10W 1% 0603 SMD	Digikey	MCR03EZPFX1400
R11	LED	140	RHM140HCT-ND	RES 140 OHM 1/10W 1% 0603 SMD	Digikey	MCR03EZPFX1400
R12	LED	140	RHM140HCT-ND	RES 140 OHM 1/10W 1% 0603 SMD	Digikey	MCR03EZPFX1400
R13	LED	140	RHM140HCT-ND	RES 140 OHM 1/10W 1% 0603 SMD	Digikey	MCR03EZPFX1400
R14	LED	140	RHM140HCT-ND	RES 140 OHM 1/10W 1% 0603 SMD	Digikey	MCR03EZPFX1400
R15	JOYSTK	150K	RHM150KFRCT-ND	RES 150K OHM 1/4W 1% 1206 SMD	Digikey	MCR18EZPF1503
R16	JOYSTK	15K	RHM15KERCT-ND	RES 15K OHM 1/4W 5% 1206 SMD	Digikey	MCR18EZPJ153
R17	JOYSTK	150K	RHM150KFRCT-ND	RES 150K OHM 1/4W 1% 1206 SMD	Digikey	MCR18EZPF1503
R18	JOYSTK	15K	RHM15KERCT-ND	RES 15K OHM 1/4W 5% 1206 SMD	Digikey	MCR18EZPJ153
R19	JOYSTK	1.6K	RHM1.60KCCT-ND	RES 1.60K OHM 1/8W 1% 0805 SMD	Digikey	MCR10EZHF1601
R20	JOYSTK	1.6K	RHM1.60KCCT-ND	RES 1.60K OHM 1/8W 1% 0805 SMD	Digikey	MCR10EZHF1601
R21	JOYSTK	1.6K	RHM1.60KCCT-ND	RES 1.60K OHM 1/8W 1% 0805 SMD	Digikey	MCR10EZHF1601
R22	JOYSTK	1.6K	RHM1.60KCCT-ND	RES 1.60K OHM 1/8W 1% 0805 SMD	Digikey	MCR10EZHF1601
R23	JOYSTK	10K	RHM10KARCT-ND	RES 10K OHM 1/8W 5% 0805 SMD	Digikey	MCR10EZPJ103
R24	JOYSTK	10K	RHM10KARCT-ND	RES 10K OHM 1/8W 5% 0805 SMD	Digikey	MCR10EZPJ103
R25	PWR	1.6K	RHM1.60KCCT-ND	RES 1.60K OHM 1/8W 1% 0805 SMD	Digikey	MCR10EZHF1601
RESET	PWR		401-1432-1-ND	SWITCH TACT SPST-NO 400GF GW SMD	Digikey	KMR243GLFG
SW1	PWR		360-2131-ND	SWITCH SLIDE SPDT 3A 125VAC PCB	Digikey	CS12ANW03
U1	PWR-6V	LM2941SX	LM2941SXCT-ND	IC REGULATOR LDO 1A TO-263-5	Digikey	LM2941SX/NOPB
U2	PWR-5V/3.3V	TLE4476	TLE4476DCT-ND	IC REGULATOR LDO DUAL DPAK-5	Digikey	TLE4476D
U3	DAC	MCP4822-PDIP8	MCP4822-E/P-ND	IC DAC 12BIT DUAL W/SPI 8DIP	Digikey	MCP4822-E/P
zzBOARD	DAC	--	ED60000-ND	IC SOCKET 8DIP .300 TIN	Digikey	210-93-308-41-001000
zzBOARD	CON8	--	AE20G-300-ND	CABLE 20 COND 300' GRAY RIBBON	Digikey	AWG28-20/G/300
zzBOARD	CON16	--	AE14G-300-ND	CABLE 14 COND 300' GRAY RIBBON	Digikey	AWG28-14/G/300
zzBOARD	CON8	--	S9321-ND	CONN SOCKET IDC 20POS W/STR GOLD	Digikey	SFH213-PPPC-D10-ID-BK-M181
zzBOARD	CON16	--	S9319-ND	CONN SOCKET IDC 14POS W/STR GOLD	Digikey	SFH213-PPPC-D07-ID-BK-M181
LCD	LCD	--	LCD-09351	Serial Enabled 128x64pix LCD 6V-7V	Sparkfun	LCD-09351
zzBOARD	PWR	--	T1071-P5P-ND	TRANS WALL 12VDC 2.0A LEVEL V	Digikey	EPSA120200U-P5P-SZ
zzBOARD	LCD	--	492-1047-ND	SPACER NYLON #2 SCREW 7/16"	Digikey	9913-437
zzBOARD	LCD	--	1ZB30	Mach Screw, Pan, 2-56 x 3/4 L, PK 100	Grainger	1ZB30
zzBOARD	LCD	--	1ZB29	Mach Screw, Pan, 2-56 x 5/8 L, PK 100	Grainger	1ZB29
zzBOARD	LCD	--	4AGF1	MICRO PLASTICS Locknut, Nylon, 2-56, 3/16 In, PK25	Grainger	MICRO PLASTICS 0700256LN
zzBOARD	BOARD	--	6RE14	Hex Standoff, #4-40x1 1/4 L, Pk10	Grainger	6RE14
zzBOARD	BOARD	--	1ZB37	Mach Screw, Pan, 4-40 x 3/8 L, PK 100	Grainger	1ZB37
zzBOARD	MTR-BOARD	--	6MY46	RICHARD MANNO CO. Hex Standoff, SS, #4-40x7/16 L, Pk10	Grainger	HST205-440-SS
zzBOARD	MTR-BOARD	--	4DFG2	MICRO PLASTICS Machine Scr, Nyl, 4-40, 3/8 L, PK50	Grainger	010440R037
zzBOARD	MTR-BOARD	--	6MU26	RICHARD MANNO CO. Hex Standoff, SS, #4-40x11/16 L, Pk10	Grainger	HMF108-440-SS
zzBOARD	MTR-BOARD	--	4DAP8	MICRO PLASTICS Flat Washer, Nylon, Fits #4, Pk 40	Grainger	MICRO PLASTICS 16FW004032