

USER'S MANUAL
VERSION 1.0b
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for

DIGITAL PULSE GENERATOR
PGEN-1 CIRCUIT BOARD

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CONTENTS

- 1.0 Introduction
 - 2.0 Circuit Description
 - 3.0 Software Description
 - 4.0 Operation
 - 5.0 PGEN Circuit Board Assembly
 - 6.0 Installation
 - 7.0 Customization
-
- Appendix A PGEN-1 Circuit Board Parts List
 - Appendix B PGEN-1 Full Kit Parts List
 - Appendix C User Supplied Parts
 - Appendix D Chassis Details
 - Appendix E RS-232 Serial Interface Connector
 - Appendix F RS-232 Communications Setup
 - Appendix G References
 - Appendix H Circuit Board Layout
 - Appendix I Schematics

PGEN Digital Pulse Generator

1.0 Introduction

The Digital Pulse Generator is designed to provide precise pulse repetition rates and duty cycles over a wide range. Continuously variable pulse generators use noisy potentiometers to set pulse widths; consequently they are difficult to set to precise values, and have unacceptable stability. The Digital Pulse Generator can be set to precise values and is as stable as its master crystal oscillator. Both pulse width (logic-1) and pulse spacing (logic-0) can be set over an eight decade range in steps of 100 nanoseconds. The TTL compatible outputs are driven by 74AC04 buffers with rise and fall times less than 10nsec. The Digital Pulse Generator can be controlled via the front panel (two switches and two push-buttons) or via RS-232. The Digital Pulse Generator can be used for missing pulse detection, tracing digital logic flow, analyzing microprocessor programs, testing radio control servos, audio testing and for many other applications requiring a precision pulse or square wave source.

1.1 Specifications

OUTPUTS

Pulse Output (J5)

- DC coupled, BNC connector, 50 ohms
- Standard TTL levels, buffered to drive up to 15 TTL loads
- Rise/fall time less than 20 nsec into 50 pFd

Optional Clock Output (J4)

- 10 or 5 MHz, selected via jumper J3
- DC coupled, BNC connector, 50 ohms
- Standard TTL levels, buffered to drive up to 14 TTL loads
- Rise/fall time less than 20 nsec into 50 pFd

MODES

Pulse Mode

- Pulse width (logic-1) and pulse spacing (logic-0) are independently adjustable from 200 nsec to 9.9999999 seconds in 100 nsec steps.

Square Mode

- Pulse width (logic 1) and pulse spacing (logic 0) are always equal.
- Frequency is adjustable from 2.5 MHz to 0.05 Hz in 200 nsec steps.

CONTROLS

- Pulse/Square toggle switch - selects the mode.

- Line toggle switch - moves LCD cursor to selected line during Pulse mode.

- Advance pushbutton - moves the LCD cursor right to the next numeric character. The cursor wraps around to the first numeric character after reaching the right-most numeric character.

- Increment pushbutton - increments the numeric character at the LCD cursor. Numeric values wrap around from 9 to 0.

POWER

- 9 volts DC at 100 mA

2.0 Circuit Description

This section describes the circuitry on the PGEN-1 circuit board.

2.1 Power Supply

Schematic sheet 1 (Appendix I) shows the power supply circuitry. D2 isolates the 9VDC wall transformer from the PGEN-1. All PGEN-1 circuitry runs on +5V, which is provided by U3, a 78S40 universal switching regulator subsystem. It is the core of a high efficiency step-down regulator capable of accepting a wide range of input voltages. The regulator is designed to deliver +5VDC at up to 100 mA of current. Ground and +5V test points are provided on the circuit board - see Appendix H.

Bypass capacitors C12-C19 (0.1 uFd) are located near integrated circuits across the board.

2.2 Microcontroller and RS-232 Serial Port

The PIC16F87 microcontroller, or PIC for short, is designated as U1 on sheet 2 of the schematics. The PIC has 4096 words of flash program memory, 368 bytes of data memory (RAM), 256 bytes of EEPROM memory, a 16-bit timer with prescaler (TMR1), an internal clock oscillator, a universal asynchronous receiver transmitter (UART), and 16 multi-functional input/output (I/O) lines. Lucid Technologies firmware is programmed in the PIC's flash memory. The PIC's internal oscillator is programmed to operate at 4 MHz.

The RS-232 serial port connector (J2) is described in detail in Appendix E. U2 is a MAX232A, 5V-powered RS-232 interface with two drivers and two receivers. One receiver/driver pair handles RS-232 data to/from the PGEN-1. The other receiver/driver pair receives RTS and sends it back to the host as CTS. RTS is also routed to the RB6 input on the PIC.

2.3 Clock and counters

The 10 MHz frequency reference for the PGEN-1, shown on schematic sheet 3, is a stable TTL crystal clock oscillator (U4). Flip-flop U8.1 is used to divide the 10 MHz reference clock by two to produce a 5 MHz clock. Both 10 and 5 MHz clocks are routed to header J3 where either can be connected via jumper to optional output connector J4.

The counters that give the Digital Pulse Generator its huge dynamic range are U6 and U7. These are LS7366R 32-bit quadrature counters with serial peripheral interface (SPI). U6 counts down the logic-0 portion of the output and U7 counts down the logic-1 portion. The chips are programmed to operate in the non-quadrature single-cycle downcounter mode. In this mode the chip counts down to zero at which point it pulses the DFLAG output low (for one 10 MHz clock cycle) then waits until the INDEX input goes low. When INDEX goes low the chip reloads the counter and begins to count down. By connecting the DFLAG output on each chip to the INDEX input on the other chip it insures that only one chip is active at any time. When the logic-0 downcounter (U6) reaches zero it pulses its DFLAG output which sets the output flip-flop (U8.2) and reloads the logic-1 downcounter. The logic-1 downcounter (U7) then counts down to zero at which time it pulses its DFLAG output which clears the output flip-flop (U8.2) and reloads the logic-0 downcounter for another cycle. The PIC has to program the counters each time a setting changes, but once programmed the counters will automatically generate the output pulse train.

2.4 LCD interface

Liquid Crystal Display (LCD) modules compatible with the PGEN-1 circuit board are shown in Appendix C. These two-line by 16-character LCD modules have an 8-bit parallel interface with 4 control lines. However the PIC is already using most of its I/O pins for RS-232 and SPI. Fortunately an 8-bit parallel output port can be connected to the SPI bus using the 74HC4094 (8-bit serial-to-parallel latch with tri-state outputs). As shown on schematic page 4, the LCD module interface is reduced to the already existing SPI bus plus 4 control lines.

The contrast of the liquid crystal display is controlled by potentiometer VR1. The LCD module is illuminated by LED back-lights. Resistor R8 limits the current to the LED back-lights.

2.5 Shift Register Inputs

An 8-bit parallel input-port was implemented with two NAND gates and a 74HC165 8-bit parallel-input/serial-output shift register. Schematic sheet 5 shows the circuit. Parallel load of the shift register occurs when the P2SIR_Select signal goes low. Data is clocked out of the shift register by the SPI_Clock signal. The inverted output is used because the shift register data is inverted again by the open-drain NAND gate (U11.3). An open-drain output is required because SPI_In is a wire-OR'ed signal.

The standard Digital Pulse Generator software uses only four of the eight parallel inputs.

3.0 Software Description

3.1 Assembler source code

The assembly language source code for the standard Digital Pulse Generator is included with the kit. The source code is well commented and highly modular. If you know PIC assembly language it should be easy to understand. If you want to learn more about PIC programming and the free Microchip Assembler (MPASM) consult some of the excellent resources on the Microchip web site (see Appendix G for the URL).

The source code begins with several blocks of comments and equates. The comments, lines that begin with a semicolon, are explanatory text that don't generate any assembly code. Equates associate understandable names with fixed numeric values. For example the decimal value 103 is used to set the UART to 2400 baud, this value is given a more understandable name via the equate:
BD2400 equ D'103'

The first block, PIC16F87 HARDWARE SETUP, has definitions of the PIC's I/O pins, memory addresses, and equates for baud rate settings. This is followed by comment blocks about the LCD display, LS7366R counter chips, and 74HC165 inputs. The next block is equates assigning names to the values for several ASCII characters.

The next three blocks are Assembler Directives, Variable Definitions, and Macros. The Assembler Directives tell the MPASM assembler to generate code for the PIC16F87 in INHX8M format and what values to place in the Configuration Registers. The Variable Definitions reserve memory registers for use by the program. For example, a serial receive subroutine will loop until eight bits are received; the bits received are counted in a variable called "bitcnt". The following line tells the assembler to reserve one byte with the name "bitcnt".

```
bitcnt res 1 ; bit count
```

Macros assign names to short blocks of code. The entire short block of code is inserted into the program wherever the macro's name is found in the op-code column.

3.2 Interrupts

The next part of the source code is the interrupt service routine. Only one interrupt is active in the standard Digital Pulse Generator software, that is the Timer 1 (TMR1) overflow interrupt. The TMR1 prescaler clocks the 16-bit counter at 250 kHz which produces an overflow interrupt every 262 milliseconds (3.815 Hz). The interrupt service routine clears the interrupt flag and increments the Timer 1 overflow counter (tmr1ofc) variable.

3.3 Subroutines

The subroutines come next in the source code. The subroutines are well documented and should be easy to follow for anyone who is familiar with PIC assembly language. The subroutines are divided into six groups.

- 1) General Subroutines, such as data conversion; hex to ascii, ascii to hex, delays, etc.
- 2) UART Subroutines, such as setting baud rates, transmitting and receiving bytes, etc.
- 3) Synchronous Serial Port Subroutines handle the low level SPI data exchanges with the LCD display, counter chips, and shift register inputs.
- 4) 32-bit Math Subroutines are required for the 32-bit counter chips. These subroutines provide 32-bit add, subtract, multiply, divide, binary to BCD, and BCD to binary.
- 5) LCD Module Interface Subroutines format data for display and coordinate the LCD's unique control lines with SPI output.
- 6) Pulse Generator Data Manipulation Subroutines parse ASCII input strings from the host, keep counter chip values within valid ranges, and swap data between 32-bit pseudo registers.

3.4 Main Program

The power on reset initialization code begins at the MAIN label. The internal oscillator is set to 4 MHz, the direction of the I/O ports is set, the TMR1 overflow interrupt is set to 3.815 Hz, the counter chips and LCD display are initialized, the start-up message is displayed and the TMR1 overflow interrupt is enabled.

The label LOOP is the top of the main program loop. The program reads RB6 to see if RTS is ON, which means a computer is connected to the RS-232 serial port (J2). If RTS is ON then program control jumps to label HOST_COM. Host communications is discussed in the next section. The program then reads and stores the input shift register byte. If there is no change in the front panel switches since they were last read the program jumps back to LOOP. If any switch has changed the program reacts to the change, updates the counter chips and display if required, then jumps back to LOOP.

3.5 Firmware modifications

Modification of the Digital Pulse Generator firmware should only be attempted by someone who is an expert in assembly language programming and possesses a PIC programmer. That being said, for the knowledgeable, the original firmware provides well documented subroutines and examples from which to learn. An easy way to try out new routines is to use option 6 on the host communications menu. The jump to this option routine is already coded but the routine only consist of a jump back to the host communication mode.

4.0 Operation

When power is applied to the Digital Pulse Generator both counters are initialized to 0.5 milliseconds. The LCD display will show "LUCID TECH. Firmware XXX"; where XXX is the version number of the installed firmware. After four seconds the display will change to that of the selected mode. See the front panel switch labels in Appendix D.

4.1 Pulse Mode Operation

Pulse mode is entered by placing the mode select switch in the PULSE position. The initial display will be:

1=0000.5000ms

0=0000.5000ms

This display is telling one that the pulse width (logic-1) is 0.5ms and the pulse spacing (logic-0) is 0.5ms. The LCD cursor will be on the first digit of the time value in the line chosen by the LINE select switch. The cursor is moved one digit to the right by pressing the ADV (digit advance) pushbutton. The cursor will move from the seconds (left-most) to the hundreds-of-nanoseconds (right-most) position as the ADV pushbutton is depressed. When the cursor is on the right-most digit the next depression of ADV will move the cursor to the left-most digit on the same line.

Toggling the LINE select switch will move the cursor to the same digit position on the other line.

The value under the cursor can be incremented by pressing the INC pushbutton. Values wrap around from 9 to 0 without a carry to the next higher digit. Whenever the INC pushbutton is depressed the output waveform (OUT) changes to reflect the values shown on the display. The other switches all change the display but do not change the output waveform.

For example, a one millisecond pulse repeated once a second would be set as:

1=0001.0000ms

0=0999.0000ms

4.2 Square Mode Operation

Square mode is entered by placing the mode select switch in the SQUARE position. The initial display will be:

P=00001.0000ms

F=0001000.00Hz

This display is telling one that the Period is 1.0ms and the pulse Frequency is 1000 Hz. The LCD cursor will be on the first digit of the Frequency value; the LINE select switch has no effect in this mode. The ADV pushbutton functions the same way it does in the PULSE mode. The value under the cursor can be incremented by pressing the INC pushbutton. Because the SQUARE mode produces a square wave (50% duty factor) the minimum change in period is 200ns, 100ns for logic-1 and 100ns for logic-0. Because of the discrete step size not every frequency value is attainable. Every time the INC pushbutton is depressed the Digital Pulse Generator will compute the attainable frequency closest to the new setting and update the counters and display to the computed value.

Note that the counter values that determine the output waveform are only changed when the INC pushbutton is pressed. Changing from one mode to another does not change the output waveform. In fact, changing modes from Pulse to Square is a convenient way to see the overall period of a waveform and its pulse repetition frequency. Consider the example from Section 4.1, a one millisecond pulse repeated once a second. In Pulse mode this would be set as follows.

1=0001.0000ms

PGEN Digital Pulse Generator

0=0999.0000ms

Toggling to mode to Square would change the display to the following without changing the output.

P=01000.0000ms

F=0000001.00Hz

4.3 Host Communication Mode

Host communication mode is entered by connecting an RS-232 cable between the Digital Pulse Generator and the COM port of a host computer. A terminal program must be operating on the host for communication with the Digital Pulse Generator (see Appendix F). When the Digital Pulse Generator senses an RS-232 connection at J2 it tries to synchronize baud rates with the host. The Digital Pulse Generator waits to receive a Return (Enter) character at 1200 baud. If it receives any other character (such as a Return at another baud rate) it doubles its own baud rate and waits for another Return at the new baud rate. If it reaches 19200 baud without receiving a Return it cycles back to 1200 baud. To synchronize the Digital Pulse Generator with the host's baud rate one simply needs to press Return (Enter) repeatedly until the Digital Pulse Generator sends the menu screen.

Digital Pulse Generator, Firmware 2.03

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0 Set low (0) time

1 Set high (1) time

2 Square wave

3 Show settings

4 Update counters

5 Store powerup settings

6 RC servo

C Command line

X Exit

?

Menu options are selected by typing the corresponding single number or character, any other entries will be ignored and the menu will be displayed again. In the following examples the text sent by the Digital Pulse Generator is in italics, the text entered by the user is regular bold.

Time values are entered in microseconds or milliseconds. Microseconds are specified by entering the number with a u or U suffix. Milliseconds are specified with an m or M suffix. Frequency values are entered in Hertz with an h or H suffix.

0 Set low (0) time

This option allows one to set the logic-0 or pulse spacing time. In the example shown here logic-0 is set to 9.25 milliseconds. The output waveform will not be changed until option 4 is selected.

?0

Low time = 9.25m

1 Set high (1) time

This option allows one to set the logic-1 or pulse width time. In the example shown here logic-1 is set to 750 microseconds. The output waveform will not be changed until option 4 is selected.

?1
High time = 750u

2 Square wave

This option allows one to specify the frequency of a square wave. In the example shown here the specified frequency is 2 kiloHertz. The Digital Pulse Generator will compute the frequency closest to the specified frequency. The actual frequency can be seen by selecting option 3. The output waveform will not be changed until option 4 is selected.

?2
Frequency = 2000h

3 Show settings

This option allows one to see the specified settings. The settings shown here are internally consistent but are not related to other examples shown in this manual.

?3
Low time = 10.0000 milliseconds
High time = 0.2499 milliseconds
Period = 10.2499 milliseconds
Frequency = 97.56 Hz

4 Update counters

This option updates the logic-1 and logic-0 counters simultaneously - or as close to simultaneous as is possible addressing two SPI peripheral chips.

?4 *Ok*

5 Store powerup settings

This option writes the current logic-0 and logic-1 pulse settings to the PIC16F87's internal EEPROM. When power is applied to the Digital Pulse Generator reads these values from the EEPROM and uses them to initialize the counters.

?5 *Ok*

6 RC servo

This option configures the output pulse train for control of a Radio Control (RC) servo. RC servos rotate in response to a variable pulse width signal. The pulse width begins at 1.5 milliseconds which corresponds to the center of rotation. The minimum and maximum pulse widths for this routine are 0.86 and 2.14 milliseconds respectively. The logic-0 or pulse spacing time is fixed at 28.5 milliseconds. Pressing the l or L key decreases the pulse width causing the RC servo to rotate left; r or R increases the pulse width causing the RC servo to rotate right. The decrease/increase step size is 10 microseconds. Pressing the escape key returns the Host menu screen. In the example shown here the L key was pressed two times.

?5
Enter L, R, ESCape to abort.
1.50
1.49
1.48

X Exit

This option terminates the Host communication mode and returns to the mode set on the mode select switch.

?x
Disconnect RS-232 cable.

C Command line

The command line interface can be used in two ways. First, it can be used from a terminal program for manual input without displaying the entire main menu. Second, it can function as the control interface for a custom computer program on the host. When writing a computer program to interface with the PGEN the program should monitor the characters received from the PGEN until it sees the '?' character which is the input prompt of the Main Menu. The program should then send a 'C' character to the PGEN to place it in command line mode. The program should send One command at a time after receiving the '>' prompt.

Each command is specified by a single ascii 'command character' sent to the PGEN following the '>' prompt. Command characters may be lower or upper case, but are always echoed as upper case. All characters sent to the PGEN, except (CR), are echoed back to the host. For commands that require data, such as setting pulse times or frequency, the data must follow the command character and be terminated by a (CR). The acceptable formats for entry of pulse time and frequency are identical to those used with the Main Menu – see section 4.3.

If the character sent to the PGEN following the prompt is not recognized as a valid command character, a (NAK)(CR)(LF)> sequence will be sent to the host. If an error is found in the numeric data following a command, an error message will be sent - see section 4.4 - followed by a (NAK)(CR)(LF)> sequence. The command is ignored whenever a (NAK) is returned instead of an (ACK).

The command line interface uses only ascii characters.

- # = ascii numeric character
- X = ascii alpha-numeric character
- () = single ascii byte
- [/] = one of two possible ascii bytes
- {error message} = one of several possible error messages

Setting the high (logic-1) time. Changes the internal register only, does not change the output waveform.

Host → PGEN [h/H]#####.#####[m/M](CR) or [h/H]#####.#[u/U](CR)
PGEN → Host (ACK)(CR)(LF)> or {error message}(NAK)(CR)(LF)>

Setting the low (logic-0) time. Changes the internal register only, does not change the output waveform.

Host → PGEN [l/L]#####.#####[m/M](CR) or [l/L]#####.#[u/U](CR)
PGEN → Host (ACK)(CR)(LF)> or {error message}(NAK)(CR)(LF)>

PGEN Digital Pulse Generator

Set the high (logic-1) and low (logic-0) times to produce a squarewave at the specified frequency. Changes the internal registers only, does not change the output waveform.

```
Host → PGEN      [f/F]#####.##[h/H](CR)
PGEN → Host      (ACK)(CR)(LF)> or {error message}(NAK)(CR)(LF)>
```

Write the current pulse settings in EEPROM for use as the initial settings at power up.

```
Host → PGEN      [p/P]
PGEN → Host      (ACK)(CR)(LF)>
```

Update the counters from the internal registers changing the output waveform.

```
Host → PGEN      [u/U]
PGEN → Host      (ACK)(CR)(LF)>
```

Return the low (logic-0) time setting followed by the high (logic-1) time setting.

```
Host → PGEN      [s/S]
PGEN → Host      (ACK)#####.#####m,#####.#####m(CR)(LF)>
```

Return the firmware version.

```
Host → PGEN      [v/V]
PGEN → Host      (ACK)X.XX(CR)(LF)>
```

Quit.

```
Host → PGEN      (ESC)
PGEN → Host      (ACK)(Return to main menu)
```

4.4 Error Messages

The routine that processes RS-232 inputs checks for obvious errors; if it finds an error the input is ignored and an error message is displayed. Examples of the error messages are explained below.

?0

Low time = 12345.789012345m INPUT TOO LONG!

Here the user entered too many digits. The maximum number of alpha or numeric characters allowed for any entry is sixteen.

?1

High time = 750y INCORRECT UNIT CODE!

Here the user made a typographical error, entering 'y' as the unit code.

?1

High time = 325h INCORRECT UNIT CODE!

Here the user should have entered a time in microseconds (u or U) or milliseconds (m or M) but he entered a frequency in Hertz.

?2

PGEN Digital Pulse Generator

Frequency = 16.6m INCORRECT UNIT CODE!

Here the user should have entered a frequency in Hertz (h or H) but he entered a time in milliseconds.

?1

Low time = 20.25u INVALID FORMAT!

Here the user specified the time down to hundredths of a microsecond. This is beyond the resolution of the PGEN because its minimum step size is 100 nanoseconds or 0.1 microsecond.

?2

Frequency = 200h NOT AN ASCII NUMBER!

Here the user intended to enter two-hundred Hertz but he typed ohs instead of zeros.

5.0 PGEN Circuit Board Assembly

5.1 Preparation

You will need the following tools:

- > A low wattage soldering pencil, approximately 10 to 20 Watts.
- > Flux core solder wire, organic flux core preferred.
- > Lead benders.
- > Lead/wire clippers.

Before beginning assemble, carefully check the PGEN circuit board for shorted or incomplete traces and confirm all parts against the list in Appendix A.

5.2 Assembly checklist

Check the value/type of each part as you assemble the board. Clip excess lead length from each component after it's soldered. See Appendix H for parts placement.

Insert and solder the low-profile sockets for:

___	U1	18-pin DIP
___	U2	16-pin DIP
___	U3	16-pin DIP
___	U5	14-pin DIP
___	U6	14-pin DIP
___	U7	14-pin DIP
___	U8	14-pin DIP
___	U9	16-pin DIP
___	U10	16-pin DIP
___	U11	14-pin DIP

Insert and solder the following components.

___	R1	1.0 ohm, 0.25W, 5%	(brown-black-gold-gold)
___	R2	30K, 0.25W, 5%	(orange-black-orange-gold)
___	R3	10K, 0.25W, 5%	(brown-black-orange-gold)
___	R4	10K, 0.25W, 5%	(brown-black-orange-gold)
___	R5	1.1K, 0.25W, 5%	(brown-brown-red-gold)
___	R6	1.1K, 0.25W, 5%	(brown-brown-red-gold)
___	R7	4.7K, 0.25W, 5%	(yellow-violet-red-gold)
___	R8	33 ohm, 0.25W, 5%	(orange-orange-black-gold)
___	R9	10K, 0.25W, 5%	(brown-black-orange-gold)
___	R10	10K, 0.25W, 5%	(brown-black-orange-gold)
___	RN1	10k, 10-pin SIP, pin 1 goes in the square pad	
___	VR1	5k, trim pot	
___	D1	1N5818, banded end toward square pad	
___	D2	1N5818, banded end toward square pad	
___	C1	560 pFd, radial	
___	C2	47 uFd, axial, positive lead toward square pad	
___	C3	100 uFd, axial, positive lead toward square pad	

PGEN Digital Pulse Generator

___ C4	100 uFd, axial, positive lead toward square pad	
___ C5	1.0 uFd, radial, positive lead toward square pad	
___ C6	1.0 uFd, radial, positive lead toward square pad	
___ C7	1.0 uFd, radial, positive lead toward square pad	
___ C8	1.0 uFd, radial, positive lead toward square pad	
___ C9	0.1 uFd, radial	
___ C10	0.1 uFd, radial	
___ C11	0.1 uFd, radial	
___ C12	0.1 uFd, radial	
___ C13	0.1 uFd, radial	
___ C14	0.1 uFd, radial	
___ C15	0.1 uFd, radial	
___ C16	0.1 uFd, radial	
___ C17	0.1 uFd, radial	
___ C18	0.1 uFd, radial	
___ C19	0.1 uFd, radial	
___ L1	150uH inductor	(brown, green, brown)
___ J1	DC power jack	
___ J2	DB9 female connector	
___ J3	3x1 jumper header	
___ U4	10 MHz clock	

The next component (J6) is the connector for the LCD module. The LCD's ribbon cable and J6 have contacts on only one side so they must mate up correctly. The rear edge of the circuit board is the edge with connectors J1 and J2.

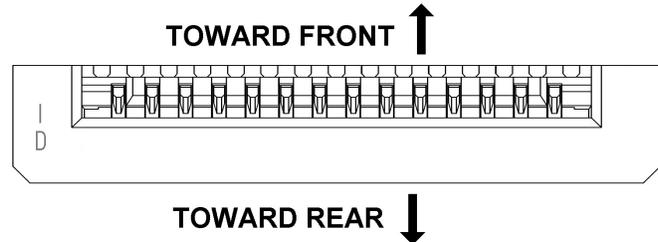


Figure 5.2 Orientation of J6

___ J6	52030-1629 LCD connector
--------	--------------------------

The wires to the switches and output connector can be soldered directly to the circuit board or connected via 2 pin headers (see picture in Appendix D). Outputs J4 and J5 are polarized; positive (+) goes to the center of the BNC connector and negative goes to the barrel of the BNC connector.

___ J4	Optional clock output positive (+) wire, approximately 2.5 inches
___ J4	Optional clock output negative wire, approximately 2.5 inches
___ J5	Pulse output positive (+) wire, approximately 5 inches
___ J5	Pulse output negative wire, approximately 2.5 inches
___ SW0	Wire 1 to Line select switch, approximately 3 inches
___ SW0	Wire 2 to Line select switch, approximately 3 inches
___ SW3	Wire 1 to Digit Advance pushbutton, approximately 2.5 inches
___ SW3	Wire 2 to Digit Advance pushbutton, approximately 2.5 inches
___ SW4	Wire 1 to Digit Increment pushbutton, approximately 3 inches
___ SW4	Wire 2 to Digit Increment pushbutton, approximately 3 inches

PGEN Digital Pulse Generator

- ___ SW5 Wire 1 to Mode select switch, approximately 3 inches
- ___ SW5 Wire 2 to Mode select switch, approximately 3 inches

The last construction step is to clean the board. If you used organic core solder just rinse the board in warm water. If you used acid core solder try scrubbing it with an old toothbrush and rubbing alcohol.

5.3 Circuit Board Checkout

You will need a multimeter and oscilloscope or logic probe to check out the PGEN circuitry. Place the PGEN circuit board on an insulating surface. DO NOT install the integrated circuits yet.

Attach the negative lead of your voltmeter to the ground test point. Plug-in your 9V wall transformer and connect it to J1 on the PGEN. The supply voltage should measure at least 8VDC on the positive lead of C2 (47 uFd). Disconnect the wall transformer at J1 then insert the 78S40 in socket U3. Reconnect the wall transformer then measure the voltage at the +5V test point. The voltage should be between 4.9 and 5.1 volts.

If there is a problem, disconnect the wall transformer and inspect the PGEN circuit board. Be sure the 78S40 is not backwards in the socket. Check that diodes D1, D2 and capacitors C2, C3, C4 are not installed backwards. Refer to schematic page 1 and check the value of all other resistors and capacitors attached to U3. Correct any errors and check +5V again.

With the wall transformer disconnected install U5 (74AC04) and U8 (74AC74). Connect the wall transformer, then use your oscilloscope or logic probe to check for the proper frequency square waves on the pins of J3; 10 MHz on the forward pin and 5 MHz on the rear pin. If both signals are absent check that U4 and U5 are not backwards. If 10 MHz is present but not 5 MHz check that U8 is not backwards.

Disconnect the wall transformer again, then insert the remainder of the integrated circuits in their sockets. The remainder of the Digital Pulse Generator checkout must wait until the front panel controls and display are connected.

6.0 Installation

6.1 Prepare the Front Panel

Assuming you are using the suggested CM5-200 case for the Digital Pulse Generator, the diagram for the front panel is shown in Appendix D. There are nine holes and one window cutout in the front panel. The picture in Appendix D shows an aluminum front panel but the plastic front panel that comes with the CM5-200 is completely adequate. Install the switches in the front panel. The bodies of the pushbutton switches should be horizontal. Install the Output BNC connector in the front panel. Finally install the LCD module. The non-metallic mounting hardware for the LCD display module is included in the kit. The ribbon

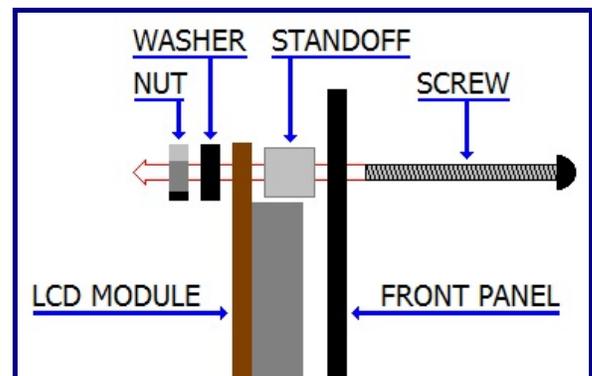


Figure 6.1 LCD mounting hardware

PGEN Digital Pulse Generator

cable is connected at the top of the LCD module. As shown in Figure 6.1, the screw goes through the front panel, through the standoff, through the circuit board on the back of the LCD module, through the washer, and finally threads into the nut. Do not over tighten! If the circuit board on the LCD module bends the nut is too tight.

6.2 Prepare the Rear Panel

The diagram for the rear panel is shown in Appendix D. There is one cutout in the rear panel that allows access to the power connector (J1) and the RS-232 connector (J2). If the optional clock output connector is used it should be installed in a 0.375 inch hole in the rear panel. The actual location is not critical so long as it clears the components on the circuit board.

6.3 Assemble the Digital Pulse Generator

Begin by identifying the bottom half of the case. The two screws that hold the case together go through the bottom half of the case. There are four short posts for mounting the PGEN board inside the case.

Place the PGEN circuit board in the bottom half of the case. Then insert the front and rear

panels in their retaining slots. Check that all the wires to the switches are connected.

Attach the PGEN circuit board to the bottom half of the case using the four self-tapping screws that came with the kit.

The correct method of connecting the LCD module's ribbon cable to J6 is not obvious, please read this entire paragraph before proceeding. Connector J6 is a Zero-Insertion-Force (ZIF) connector. The ribbon cable is inserted into J6 while it is in the open position. When J6 is in the closed position the ribbon cable is held firmly in place. Inserting or removing the ribbon cable while J6 is in the closed position can damage the contacts on the ribbon cable. Figures 6.3 show J6 from the narrow side in the open and closed positions. If the top of J6 was pushed down to the closed position during

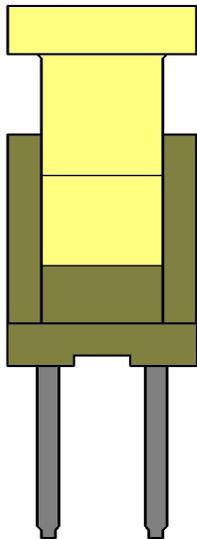


Figure 6.3a Open

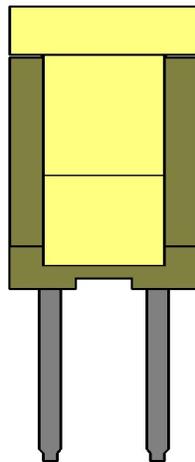


Figure 6.3b Closed

circuit board assemble, gently pull it up to the open position. Insert the LCD module's ribbon cable into J6. It should slide in with little or no resistance. Place a finger on each side of the ribbon cable and press the top of J6 down to the closed position.

6.4 Final Checkout

Connect your 9V wall transformer to J1. The LCD module should light up and display "LUCID TECH." and the firmware version. After four seconds the display will change to that of the selected mode. If nothing is displayed on the LCD module check the +5V test point. If the voltage is low an IC may be inserted backwards. If the display is working correctly proceed to check all the switches. Finally, confirm the pulse output with an oscilloscope.

7.0 Customization

The PGEN circuit board does not need to be installed in the CM5-200 case suggested by this manual. That case's small front panel limits the number of controls. In a larger case there could be, for example, two switches to move the cursor left and right; or two buttons to increment and decrement the value at the cursor. The suggested configuration uses only four inputs from the 8-bit parallel input-port leaving four more inputs available. Obviously adding more controls will require changes in the firmware.

APPENDIX A

PGEN-1 CIRCUIT BOARD PARTS LIST

Quantity	Part	Reference	
1	560pF, 35V, radial	C1	
1	47uF, 35V, axial	C2	
2	100uF, 25V, axial	C3,C4	
4	1.0uF, 50V, radial	C5 - C8	
11	0.1uF, 35V, radial	C9 - C19	
1	1.0 ohm, 0.25W, 5%	R1	(brown-black-gold-gold)
1	30K, 0.25W, 5%	R2	(orange-black-orange-gold)
4	10K, 0.25W, 5%	R3,R4,R9,R10	(brown-black-orange-gold)
2	1.1K, 0.25W, 5%	R5,R6	(brown-brown-red-gold)
1	4.7K, 0.25W, 5%	R7	(yellow-violet-red-gold)
1	33 ohm, 0.25W, 5%	R8	(orange-orange-black-gold)
1	10K, 10-SIP, pin-1 common	RN1	
1	5K trim pot	VR1	
2	1N5818, 30V	D1,D2	
1	PIC16F87-I/P, 18-DIP	U1	
1	MAX232CPE, 16-DIP	U2	
1	78S40, 16-DIP	U3	
1	10MHz clock, 14-DIP	U4	
1	74AC04, 14-DIP	U5	
2	LS7366R, 14-DIP	U6,U7	
1	74AC74, 14-DIP	U8	
1	74HC4094, 16-DIP	U9	
1	74HC165, 16-DIP	U10	
1	74HC03, 14-DIP	U11	
1	18-DIP socket	U1	
4	16-DIP socket	U2,U3,U9,U10	
5	14-DIP socket	U5 - U8,U11	
1	DC power jack	J1	
1	DB9 female connector	J2	
1	3x1 jumper header	J3	
2	2x1 output header	J4,J5	
1	52030-1629 LCD connector	J6	
1	150uH	L1	
1	PGEN-1 circuit board		
1	Jumper		

APPENDIX B

PGEN-1 FULL KIT PARTS LIST

The full PGEN-1 kit supplied by Lucid Technologies includes all the circuit board parts shown in Appendix A plus the following:

Four self-tapping screws for mounting the printed circuit board in a plastic case.

LCD module mounting hardware -

Four screws, #2, 0.5 inch long, nylon

Four nuts, #2, nylon

Four standoffs, 4 mm long, nylon

Four washers, plastic

The PGEN-1 kit sold by Lucid Technologies does not include all the parts necessary for a fully functional Digital Pulse Generator. Lucid Technologies recommends the case, switches and display listed in Appendix C.

APPENDIX C

USER SUPPLIED PARTS

The chassis parts list includes all parts not located on the circuit boards. Some suggested sources and part numbers are given. Where equivalent parts are known, multiple part numbers are shown. Other equivalent parts may be available from other sources.

Plastic case, 1 required, PacTec model CM5-200

PacTec Enclosures	www.pactecenclosures.com	610-361-4200
Black	Part# 64025-510-000	
Bone	Part# 61956-510-039	
Mouser Electronics	www.mouser.com	800-346-6873
Black	Part# 616-64025-510-000	
Bone	Part# 616-61956-510-039	

Toggle switches, miniature, SPST, Off-On, 2 required for Pulse/Square and Line Select switches

Jameco Electronics	www.jameco.com	800-831-4242
	Part# 76523	

Pushbutton switches, snap-action, miniature, momentary, Normally Open, 2 required for Digit Advance and Digit Increment switches

Jameco Electronics	www.jameco.com	800-831-4242
	Part# 596799	

BNC connector, 50 ohm, bulkhead, 1 required (output), 1 optional (clock out)

Jameco Electronics	www.jameco.com	800-831-4242
	Part# 658427	

LCD module, 1 required

Mouser Electronics	www.mouser.com	800-346-6873
	Part# HDM16216L-S-L30S	
	Part# 763-NHD-02161ZFSYYBW	
Newhaven Display	www.newhavendisplay.com	847-844-8795
	Part# NHD-02161Z-FSY-YBW-C	

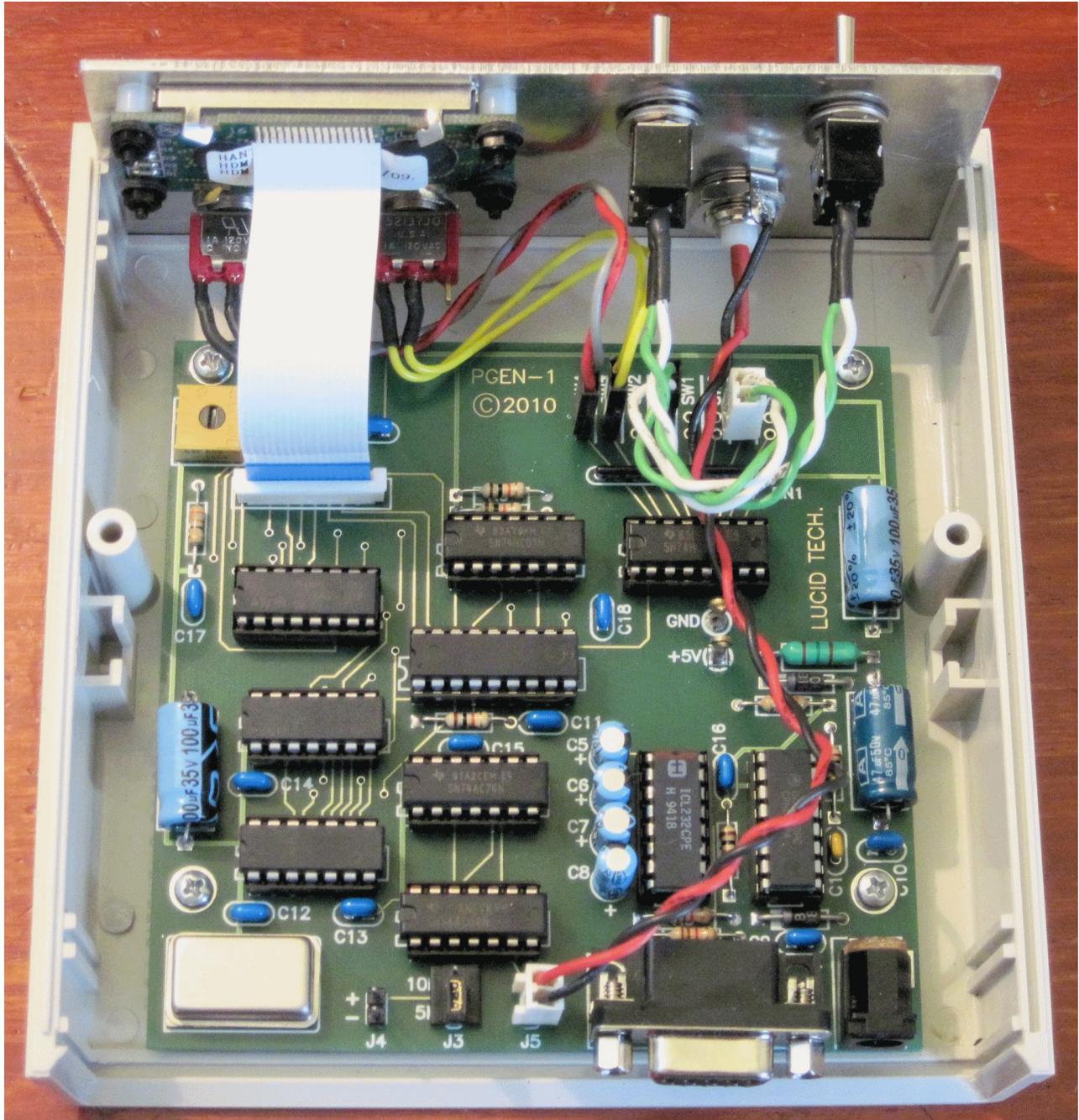
Wall transformer, 9VDC, 100 mA or more, coaxial power plug, 5.5mm O.D., 2.1mm I.D., center positive, 1 required

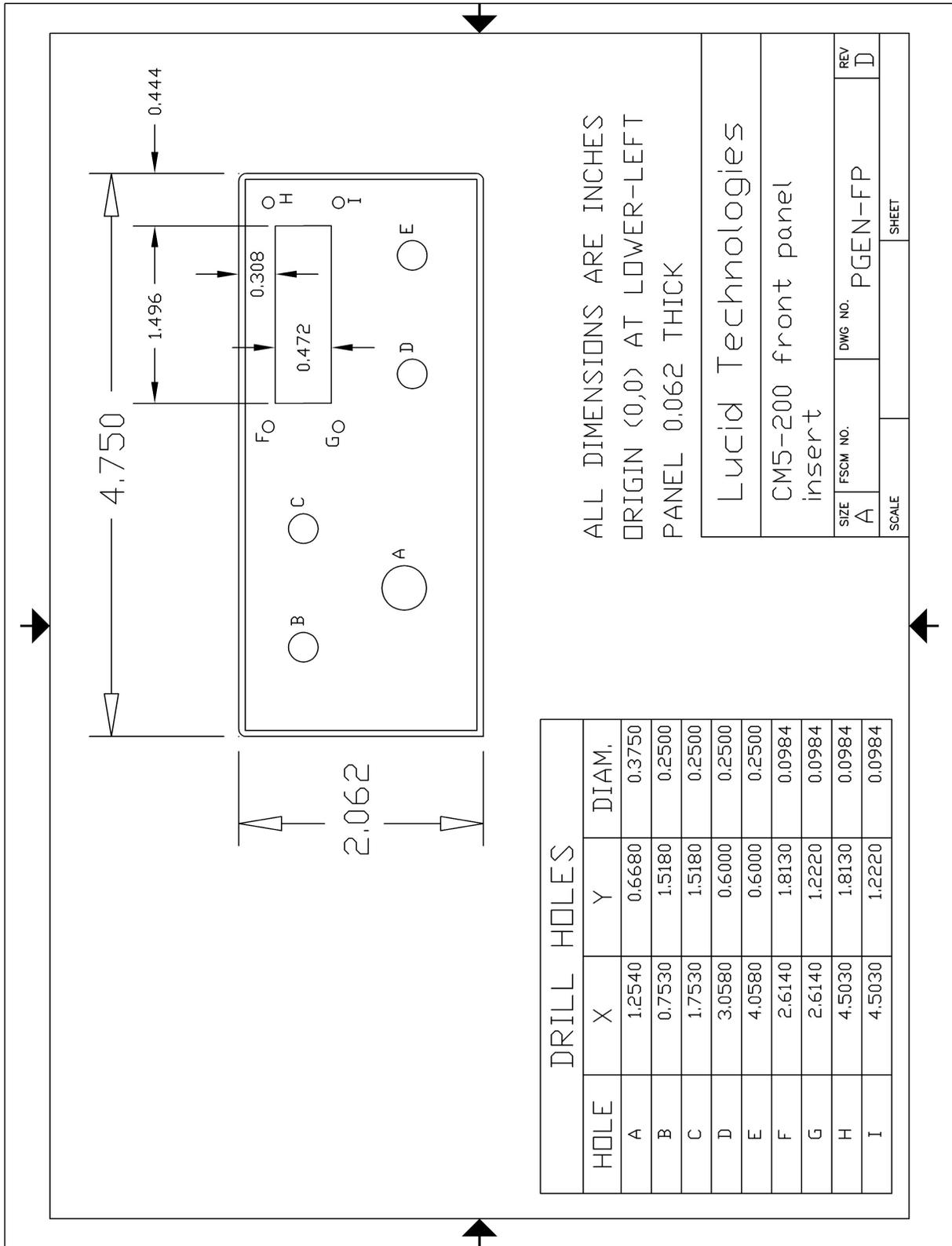
Jameco Electronics	www.jameco.com	800-831-4242
	Part# 100845	
Mouser Electronics	www.mouser.com	800-346-6873
	Part# 553-WDU9-100	

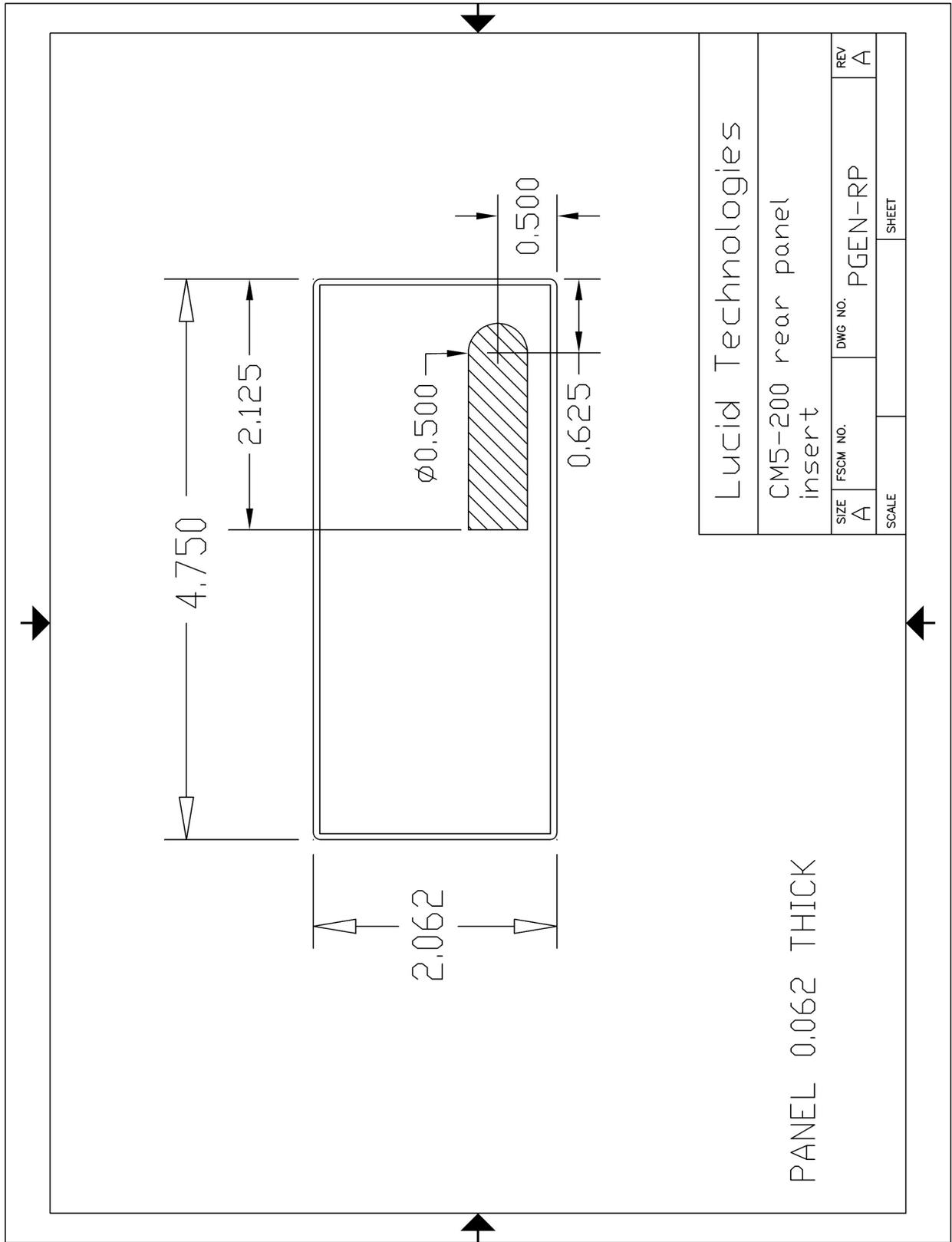
APPENDIX D

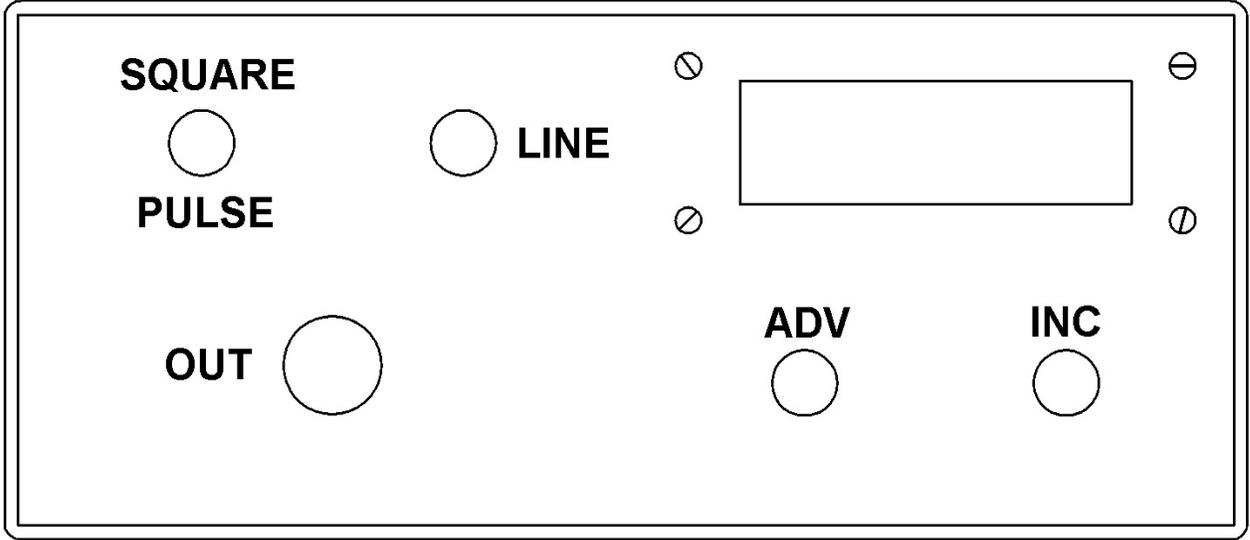
CHASSIS DETAILS

The following drawings and pictures are based on the recommended CM5-200 case. The picture shows an aluminum front panel but the plastic panel that comes with the CM5-200 works just fine.

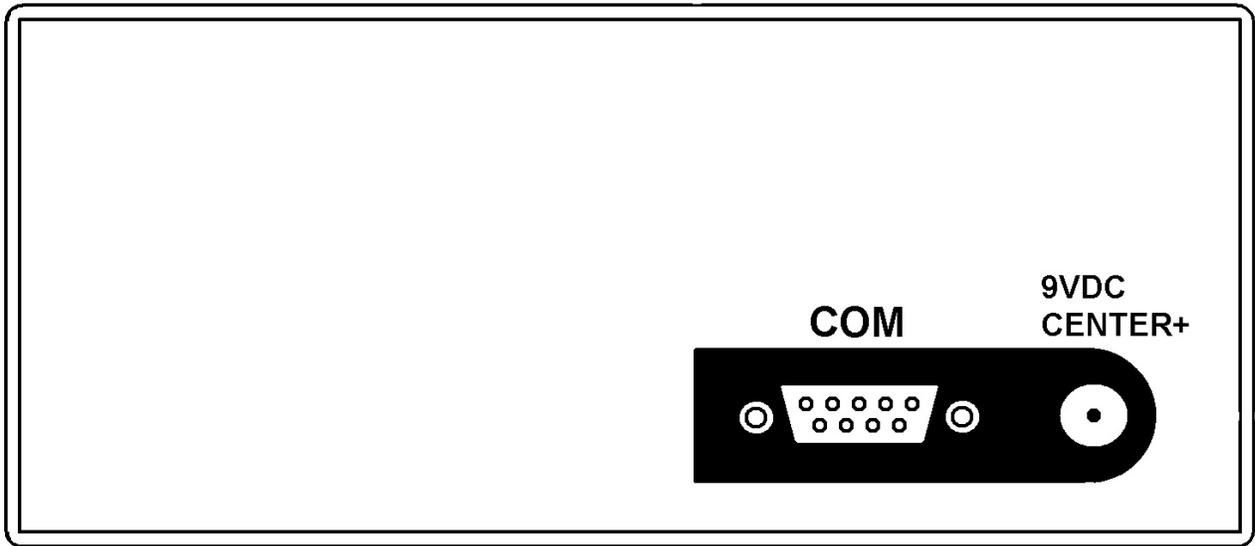








Front panel labels



Rear panel labels

APPENDIX E

RS-232 SERIAL INTERFACE CONNECTOR

The table below shows the most commonly implemented signals and their pin assignments in accordance with RS-232D. Host computers are usually DTE (Data Terminal Equipment) and modems are DCE (Data Communications Equipment). Note that circuits are named from the point of view of the DTE. For example, circuit BB (receive data) is actually data transmitted by the DCE. DCE devices originally used a 25 pin, female, D connector.

Pin	Circuit	Description	Direction
1	AA	Protective ground, PG	n/a
2	BA	Transmit data, TD	to DCE
3	BB	Receive data, RD	from DCE
4	CA	Request to send, RTS	to DCE
5	CB	Clear to send, CTS	from DCE
6	CC	Data set ready, DSR	from DCE
7	AB	Signal ground, SG	n/a
8	CF	Data carrier detect, DCD	from DCE
20	CD	Data Terminal ready, DTR	to DCE
22	CE	Ring indicator, RI	from DCE

In recent years all personal computer have migrated to the use of a 9 pin, male, D connector instead of the 25 pin connector. The pin assignments for such a DTE device are shown below.

Pin	Circuit	Description	Direction
1	CF	Data carrier detect, DCD	from DCE
2	BB	Receive data, RD	from DCE
3	BA	Transmit data, TD	to DCE
4	CD	Data Terminal ready, DTR	to DCE
5	AB	Signal ground, SG	n/a
6	CC	Data set ready, DSR	from DCE
7	CA	Request to send, RTS	to DCE
8	CB	Clear to send, CTS	from DCE
9	CE	Ring indicator, RI	from DCE

PGEN Digital Pulse Generator

All Lucid Technologies products are designed as DCE devices. They use a 9 pin, female, D connector that is directly compatible with 9 pin COM ports found on personal computers. The pin assignments for this connector are shown below.

Pin	Circuit	Description	Direction
1	CF	Data carrier detect, DCD	from Digital Pulse Generator
2	BB	Receive data, RD	from Digital Pulse Generator
3	BA	Transmit data, TD	to Digital Pulse Generator
4	CD	Data Terminal ready, DTR	to Digital Pulse Generator
5	AB	Signal ground, SG	n/a
6	CC	Data set ready, DSR	from Digital Pulse Generator
7	CA	Request to send, RTS	to Digital Pulse Generator
8	CB	Clear to send, CTS	from Digital Pulse Generator
9	CE	Ring indicator, RI	from Digital Pulse Generator

None of the handshake lines are actively controlled by the Digital Pulse Generator. DTR is not connected and thus is ignored. DSR and DCD are hard-wired to the ON condition (ON = spacing = +voltage) at all times. RTS is received, buffered, and looped back to the host as CTS; thus CTS tracks RTS.

APPENDIX F

RS-232 COMMUNICATIONS SETUP

Newer PCs may not possess a COM port but communication is still possible via a USB-to-Serial-Adapter (such as the IOGEAR GUC232A).

Your host computer must run a terminal emulation program to communicate with the Digital Pulse Generator. Several freeware terminal emulation programs are available. We will use HyperTerminal here as an example because it came bundled with all versions of Microsoft Windows prior to Vista. If you're using Vista you can download Hyperterminal for free here: <http://www.hilgraeve.com/htp/>. For older versions of Windows, if HyperTerminal wasn't part of your original installation you can add it now by going to the Control_Panel and double-clicking on Add/Remove_Programs. Select the Windows_Setup tab, then under Components, click the Communications line and the Details button. Be sure HyperTerminal is selected and click OK. When the Add/Remove_Programs window returns click OK. For Windows XP HyperTerminal can be found at: Start / All Programs / Accessories / Communications. When you first start HyperTerminal a Connection_Description window will come up. Enter a name, such as "PGEN", and select an icon, then click OK. A Connect_To window will come up. Go to the Connect_Using line and select the COM-port you will use to connect to the Digital Pulse Generator; then click OK. Remember, this is a direct connection, you are not going through a modem. A COMX_Properties window will come up next. Make the following settings:

Data bits = 8
Parity = None
Stop bits = 1
Flow control = None, then click OK.
Select a baud rate between 1200 and 19200

Now click on the File menu, Properties, and select the Settings tab. Set Emulation to ANSI. Click on the ASCII_Setup button. Set the Line_delay to 1 millisecond and the Character_delay to 0 milliseconds. Click the OK button for the ASCII_setup window and the OK button on the Properties window.

The last step in the setup is to save the terminal settings so you won't have to go through this process every time you use HyperTerminal. Click on the File menu, Save_as, check that the file name is correct, (for example PGEN.ht) and click on Save. The next time you want to run HyperTerminal you can simply double-click on the file name (PGEN.ht) and HyperTerminal will begin with all the correct settings.

Connect your Digital Pulse Generator to the COM-port and turn it on. Keep pressing Enter (Return) on your keyboard until the Digital Pulse Generator sends the main menu. After the Digital Pulse Generator senses the RS-232 connection it waits for a Return character. The Digital Pulse Generator cycles through the baud rates from 1200 to 19200 until it sees a Return.

APPENDIX G

REFERENCES

Hantronix Inc. (www.hantronix.com)

Data Sheet - HDM16216L-S, 16-character x 2-line liquid crystal display Module

LSI Computer Systems (www.lsicsi.com)

Data Sheet - LS7366R, 32-bit quadrature counter with serial interface

Maxim (www.maxim-ic.com)

Data Sheet - DS1305, Serial Alarm Real-Time Clock, REV: 070705

Microchip (www.microchip.com)

PIC16F87/88 Data Sheet, DS30487C

National (www.national.com/analog)

Data Sheet - LM78S40 Universal Switching Regulator Subsystem

Newhaven Display International (www.newhavendisplay.com)

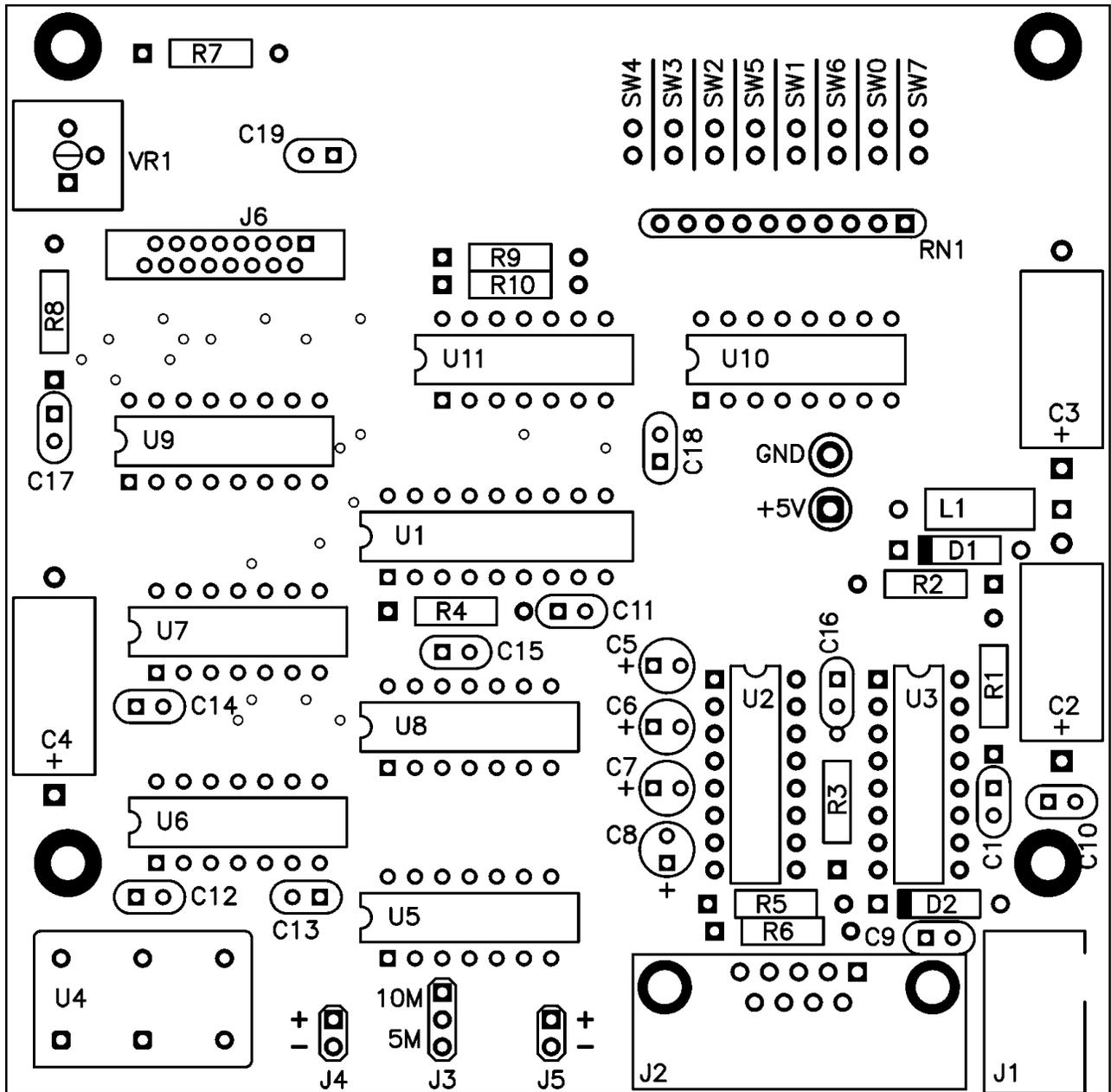
Data Sheet - NHD-02161Z-FSY-YBW-C, 16-character x 2-line liquid crystal display Module

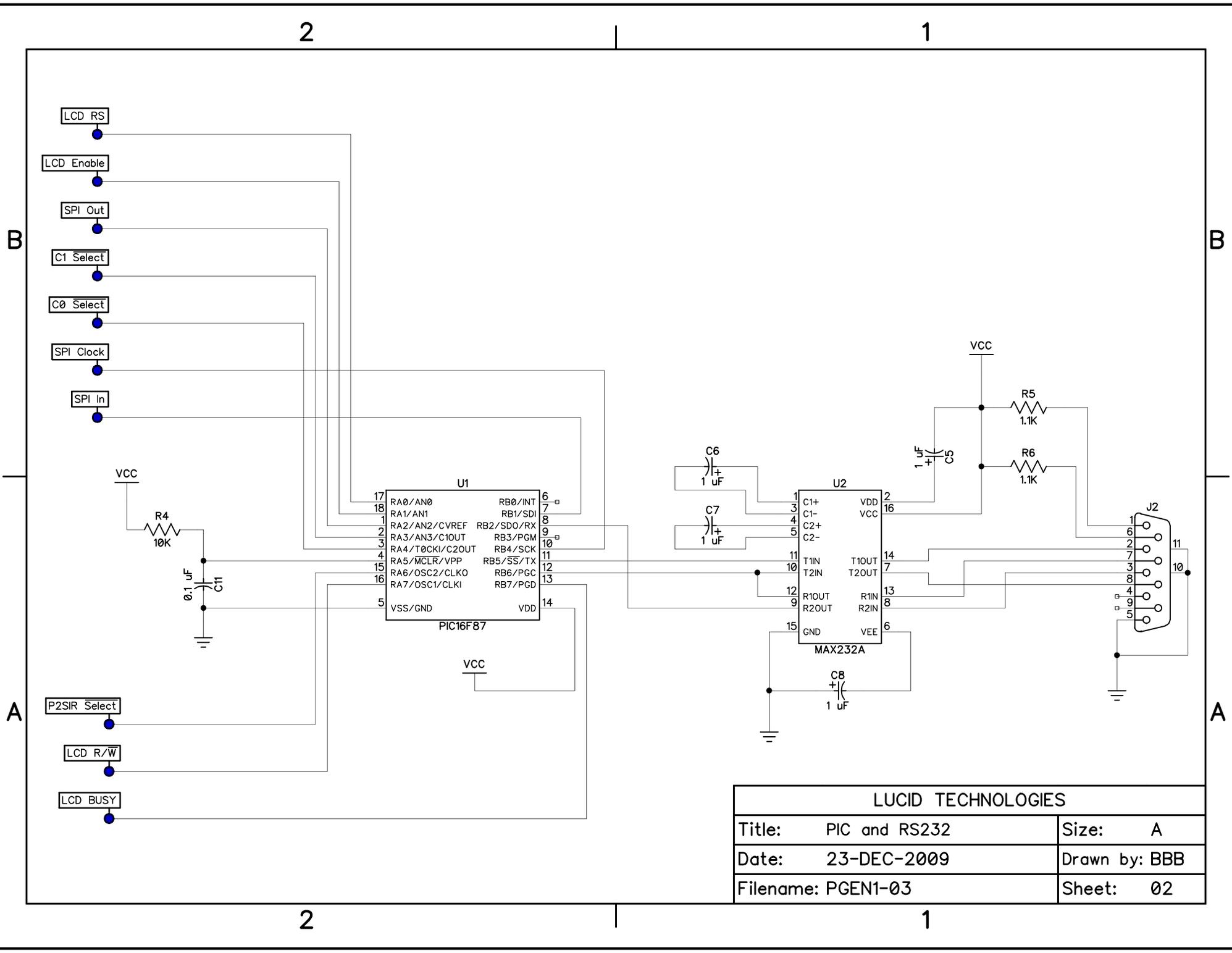
On Semiconductor (www.onsemi.com)

Application Note 920 - Theory and applications of the MC34063 and uA78S40 switching regulator control circuits

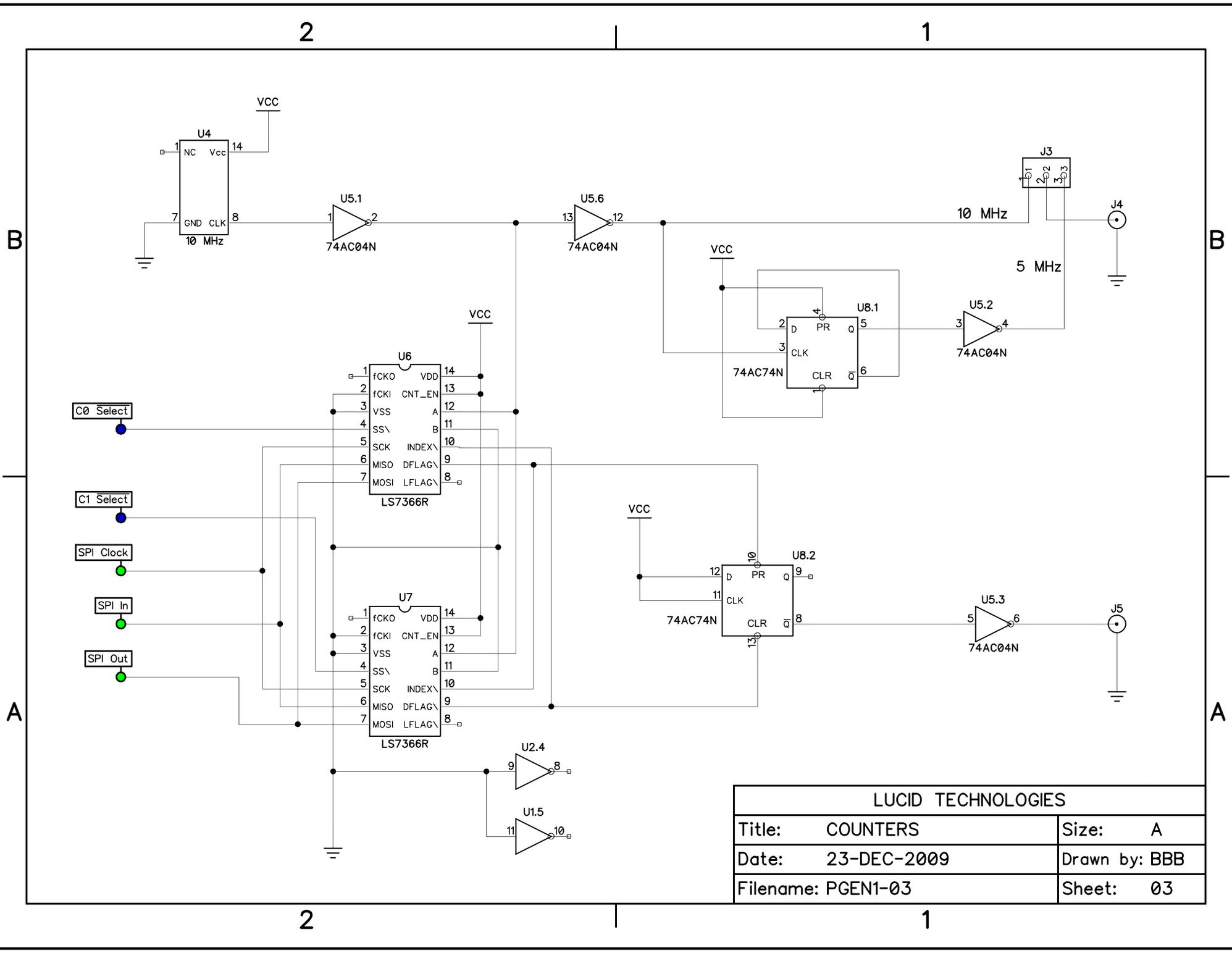
APPENDIX H

PGEN-1 CIRCUIT BOARD

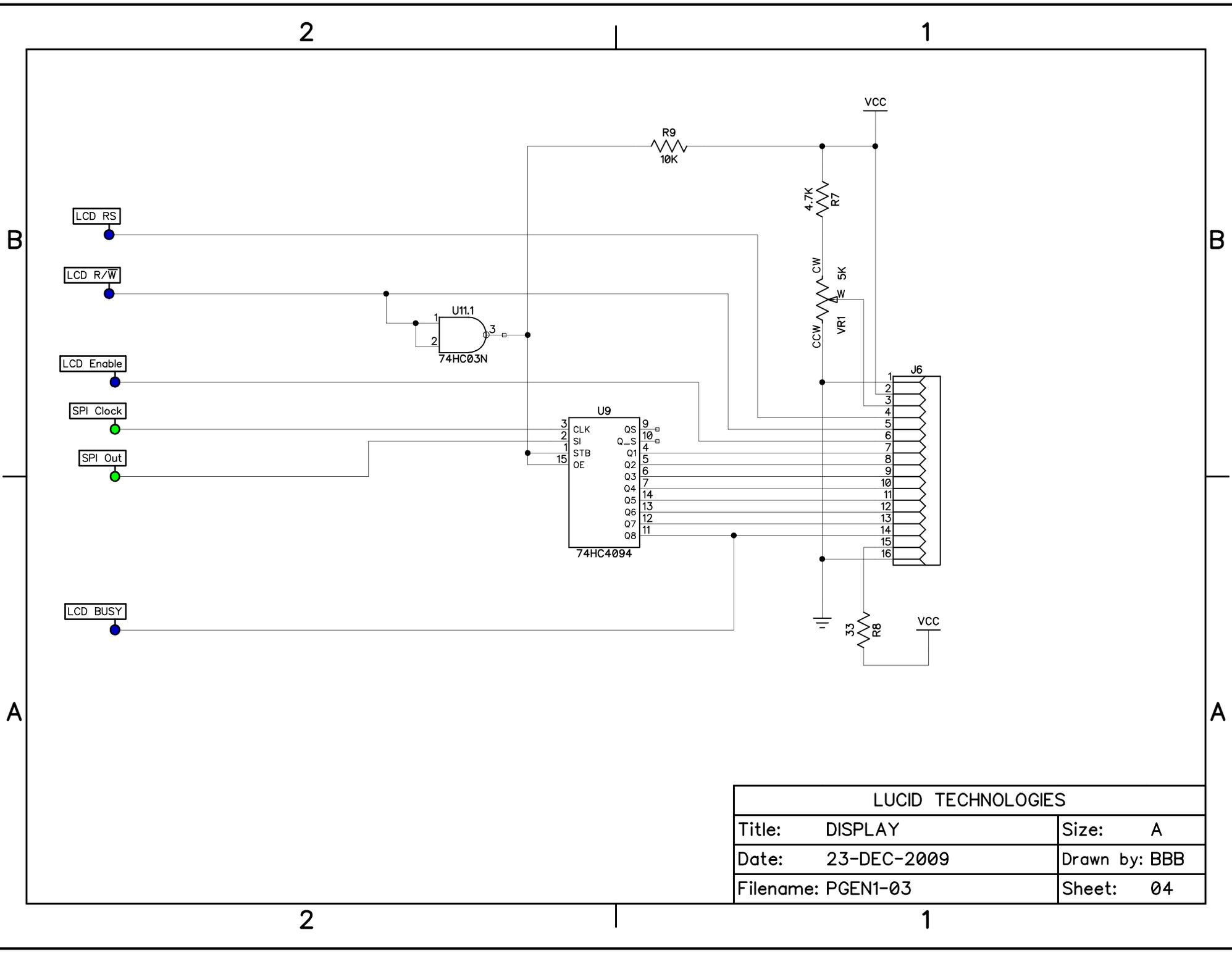




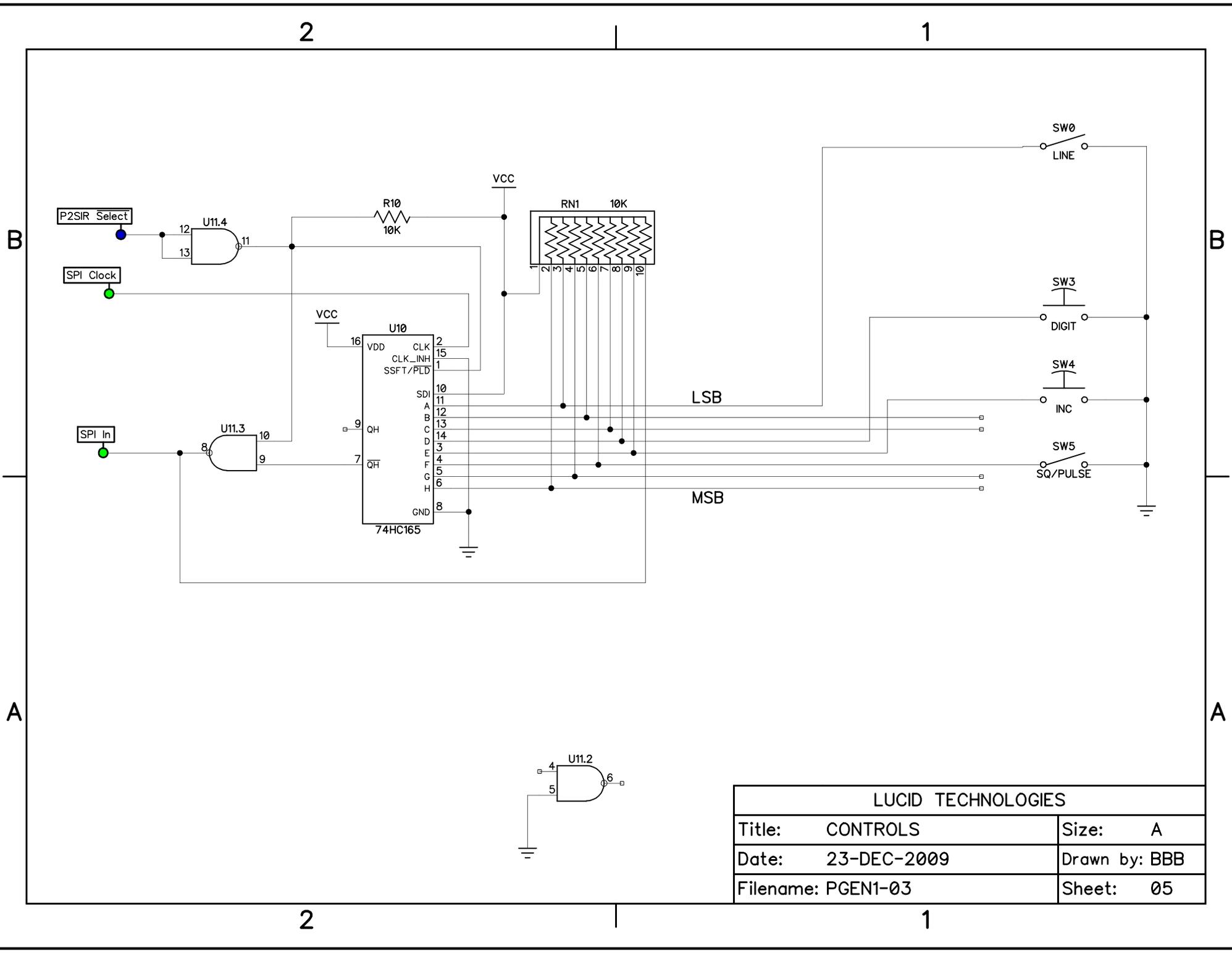
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Date:	23-DEC-2009	Drawn by:	BBB
Filename:	PGEN1-03	Sheet:	03



LUCID TECHNOLOGIES			
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Date:	23-DEC-2009	Drawn by:	BBB
Filename:	PGEN1-03	Sheet:	04



LUCID TECHNOLOGIES			
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