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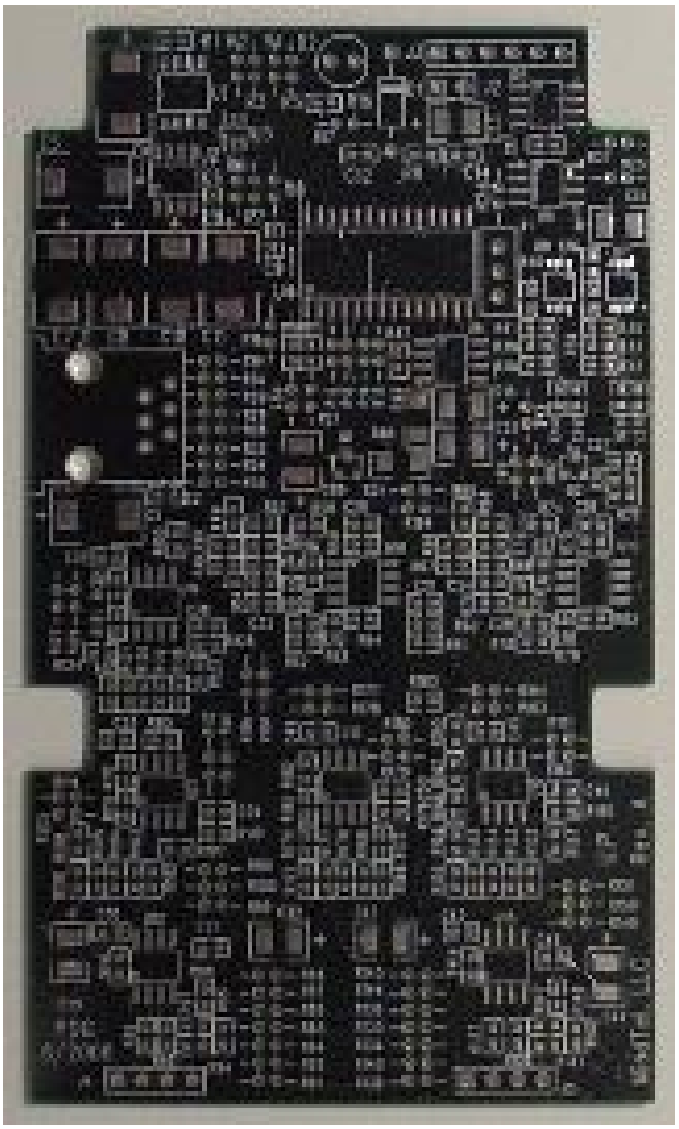
Universal Preamplifier Printed Circuit Board.



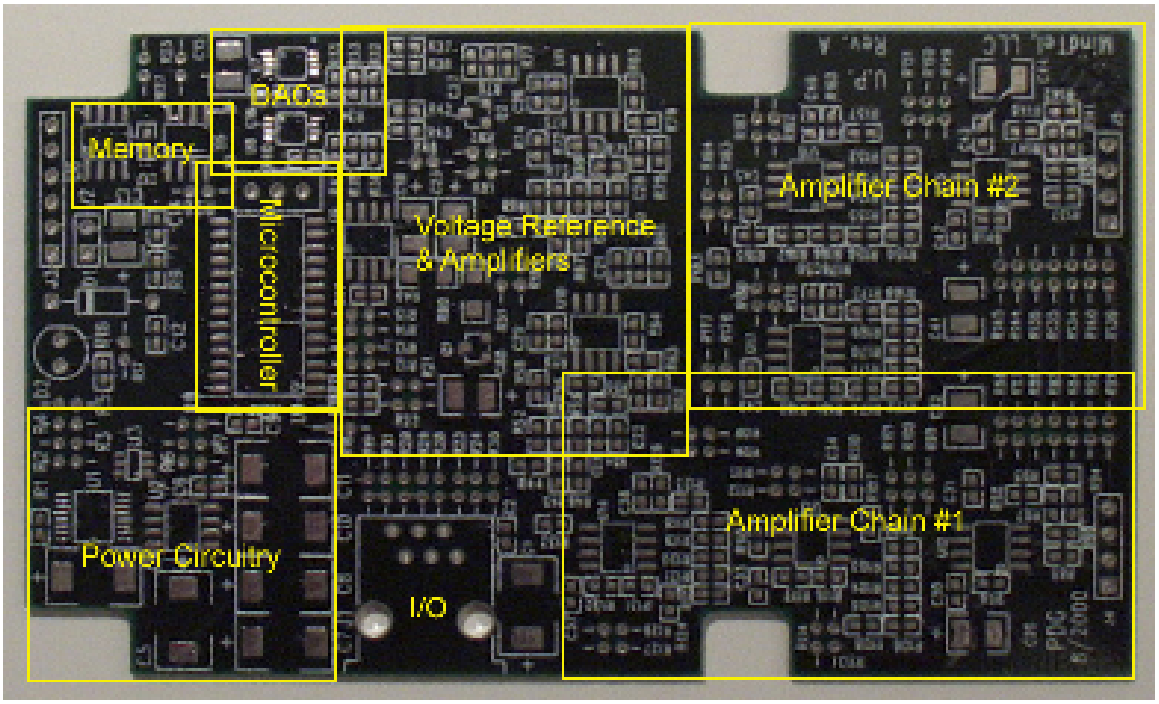
With the advent of surface-mount devices, prototyping analog circuits became problematic. This board is designed to address some of those problems.

When most components came with leads on tenth-inch centers, circuits could be easily prototyped with standard solderless breadboards and jumper wires. This can still be done if you solder the ICs to carrier boards. Capital Advanced Technologies Inc. makes a line of carrier boards that they call “Surfboards”, and Digi-Key sells them. The cost of the boards has come down in recent years, but it still costs around $5 per IC plus the cost of the breadboard.

SenSyr designed the Universal Preamp PCB (UPP) to allow rapid prototyping of common analog circuits using surface-mount components. The resultant circuit fits into a standard PacTec HML enclosure (www.pactecenclosures.com/Plastic-Enclosures/HML.html). The UPP is a 4-layer PCB roughly 2.5 x 4.3 inches. Layer 2 of the UPP is a ground plane. You'll need good to excellent soldering skills and knowledge of electronic circuits to use this board successfully. This document is not intended to be a primer on circuit design.

Sections

Full circuit diagrams are available at the end of this document. As both the diagram below and the circuit schematics show, the UPP is divided into several functional, interrelated sections.



The UPP supports a 28-pin Microchip microcontroller (including an in-circuit programming header), EEPROM memory, DACs, power circuitry, voltage reference circuitry, and two analog amplifier chains. Each amplifier chain starts with an instrumentation amplifier and includes two subsequent single op-amp stages. The board expects to see +5V power coming in. Power circuit options allow for single-ended, ±5V, and ±10V power schemes. Nowadays, single-ended designs are preferable. The microcontroller allows for a variety of analog and digital solutions. The voltage reference section allows for biasing the analog circuits with precision voltages.

Using the UPP involves coloring outside the lines quite a bit. The resistor and capacitor values are typically unspecified, because they are application circuit dependent. Use any instrumentation amplifier, operational amplifier, or voltage reference that is pin-compatible with the footprints provided. There are no particular rules (Although there are laws—Ohm's Law, Kirchhoff's Law, etc.). If it makes sense, use a capacitor in place of a resistor, or vice versa. Use jumper wires. Instead of two amplifier chains with 2 op-amps each, you can chose to implement a single chain with 3 or 4 op-amps. If you don't need it, don't populate it. Be creative. The core idea is making it easier to craft serviceable prototype circuits using surface-mount devices.

I/O Connector

A RJ-12 connector, J1, can connect the UPP to an external device and power (see Appendix A3). Ground is applied to pin 1, and +5V to pin 6. The remaining 4 pins are signal lines (primary, secondary, third, and fourth) that can be implemented in many ways.

On the UPP all the “resistors” shown with a “J” value are actually wire jumpers. Soldering a bare wire across that connection selects that connection. 0603-sized components can be soldered across the jumper holes if desired.

The four signal pins on the I/O connector can be configured to be analog or digital, and they can be connected to one or more pins on the microcontroller, if desired. For example, the “primary” signal line can be connected via installed jumper(s) to the analog chain 1 output, microcontroller pins RC2 or RB5, or the output of a DAC.

Power

V_{CC} comes into the UPP on pin 6 of J1. This is usually +5V and is used to power the microcontroller and associated circuitry. Analog IC power can be configured as single-ended (V_{CC} and ground), ±5V, or ±10V, depending on the population of U1, U2, and U3. U1 accepts a MAX864EEE that can source up to 20 mA for ±10V operation. Alternatively, population of U2 with a MAX680CSA (or equivalent) IC can supply 10 mA of ±10V power. Population of U3 with a MAX1720 (or equivalent) IC allows for ±5V operation with supply currents of 25 mA or less. The amount of available V_{CC} power depends entirely on the external source. Generally, it is preferable to use low or micro-power devices on the UPP. Ample opportunities for bypass are provided on the UPP. Generally, footprints for both tantalum bypass capacitors and 0603-sized ceramic capacitors are provided.

Microcontroller and EEPROM

Almost any 28-pin Microchip microcontroller can be used on the UPP. Although, some of the newer devices do require lower operating voltages and use a pin or two differently. The microcontroller can be used to process analog or digital signals. Up to two MAX5302 (or equivalent) DACs (U7 and U8) can be connected to the microcontroller via SPI. The UUP supports either a 25LC160 (U5) or 93C76/86 (U6) EEPROM for external data storage. Other EEPROMs with compatible footprints may also be used. Many microcontrollers have some EEPROM memory built-in, however.

There is a provision for an on-board LED indicator connected to the RA4 pin. That pin is normally open-drain (collector), and consequently requires the V_{CC} bias allowed by R16.

In-circuit programming is supported via the J3 6-pin header. The J2 jumper can be installed as a two-pin header with a removable shunt to allow board power for programming, or removed to accommodate the application of programmer power without energizing the rest of the circuit. You'll need to make an adapter cable in order to use your favorite programming device (ICD2, for example).

ICD2 Pin	J3 Programming Header Pin
1 Vpp/MCLR-	1 Vpp/MCLR-
2 Vdd	2 Vcc
3 Vss	3 Gnd
4 PGD	5 RB7
5 PGC	6 RB6
6 No Connection	4 No Connection

Some of the newer microcontrollers have an internal oscillator. That means that X1 can go unpopulated and the two pins used for debugging (or other) purposes.

DACs

U7 and U8 can be populated with MAX5302 (or equivalent) DACs—digital-to-analog converters. The data interface for these DACs is the SPI microcontroller bus. RB1 and RB0 are the select lines for U7 and U8, respectively. The select lines are inverted logic lines, so they should be held at the logic-1 level normally. Operation of the DACs requires the presence of a microcontroller programmed to support the DAC. The DACs have an op-amp output. This allows their gain and offset to be manipulated depending on how R33 through R37, and R39 through R43 are populated. V_{REFH} and V_{REFL} are available for offsetting the DAC outputs. The DAC outputs of U7 and U8 can be directed to the primary or secondary I/O connector lines, respectively. Alternatively, the DAC outputs can be redirected back to the analog section via jumper wire.

Voltage Reference

Voltage references are important when working with single-ended op-amp circuits, strain gauge circuits, etc. A stable voltage that's able to source or sink a reasonable amount of current is essential to modern analog circuit design. U9 can be populated with any REF19x reference voltage IC (or equivalent). The REF192ES IC provides a stable 2.5V reference that can source/sink 25 mA. The U10 and U11 op-amp circuitry can be used to provide derivative voltages or enhance current (with Q1 and or Q2). In a pinch, you can press U10 and U11 into service as part of your analog circuit application.

Amplifier Chains

The UPP nominally supports two amplifier chains. Each chain is made up of an instrumentation amplifier (in-amp) and two following single operational amplifiers (op-amps). Other configurations are possible through creative soldering. The reference section can be used to generate stable offset voltages. The amplified signal can be digitized by an installed microcontroller when connected by appropriate jumpers. Using the voltage reference circuitry with a DAC could be used to implement a programmable voltage as a reference or offset in the amplifier chain.

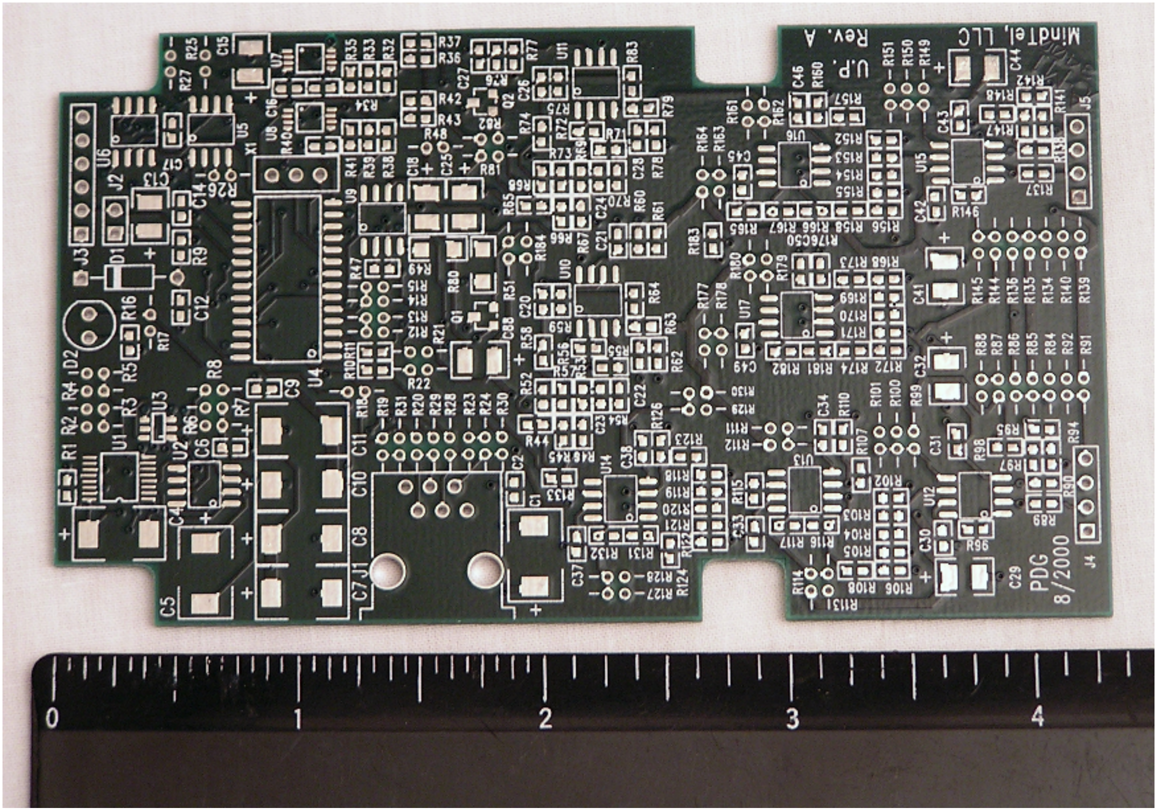
Instrumentation Amplifier

The instrumentation amplifier can be practically any 8-pin instrumentation amplifier or something like the AD629 difference amplifier. Picking the perfect in-amp or op-amp for your application is beyond the scope of this document, but we'd like to remind you to pay special attention to the input common-mode range when selecting in-amps. Possible in-amp candidates include the AD623 and INA128/129.

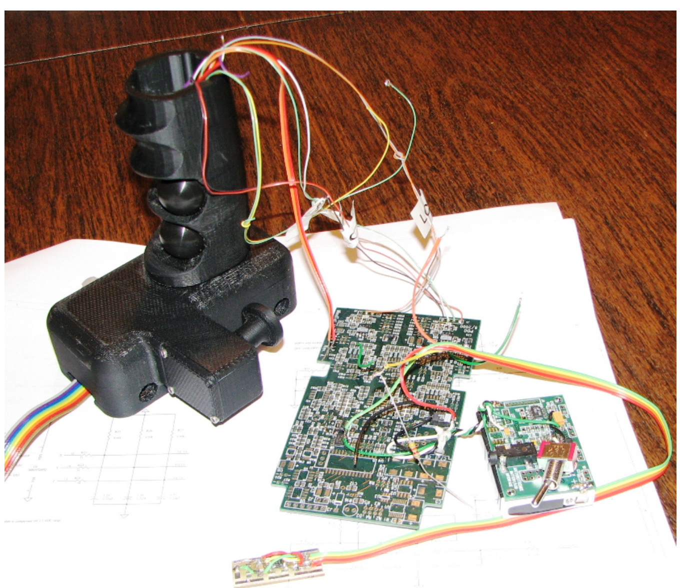
The J4 and J5 headers are for external signal inputs into the first stage of each amplifier chain. The header connections depend on the implemented power scheme and the nature of the device connected through the header. For example a 4-arm strain gauge bridge.

Op-Amps

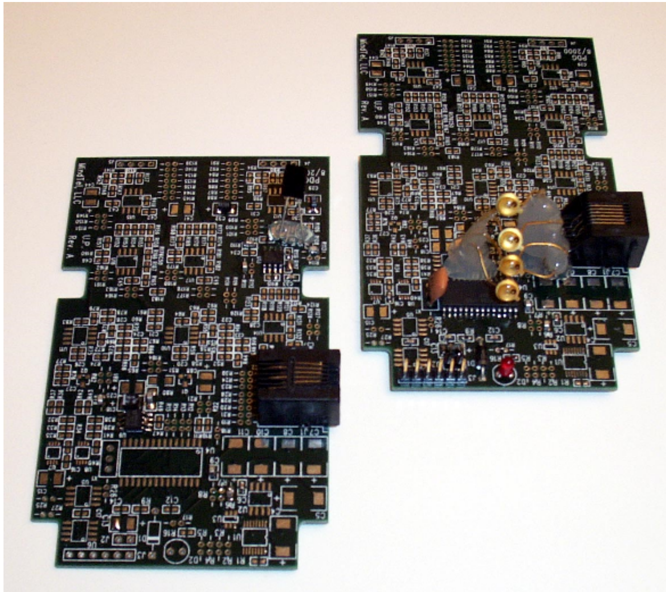
Each amplifier chain connects up to two amplifiers after the in-amp stage. These amplifiers can be used for filtering the input signal and increasing gain. There are lots of suitable op-amps. Odds are good that your favorite will work with the UPP. For example, the OPA337.



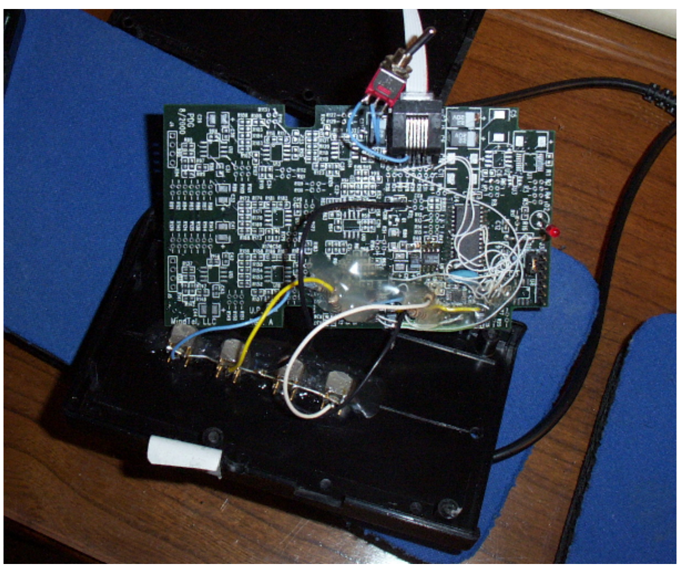
UUP Close-Up



Test Circuit for a Strain Gauge Amplifier

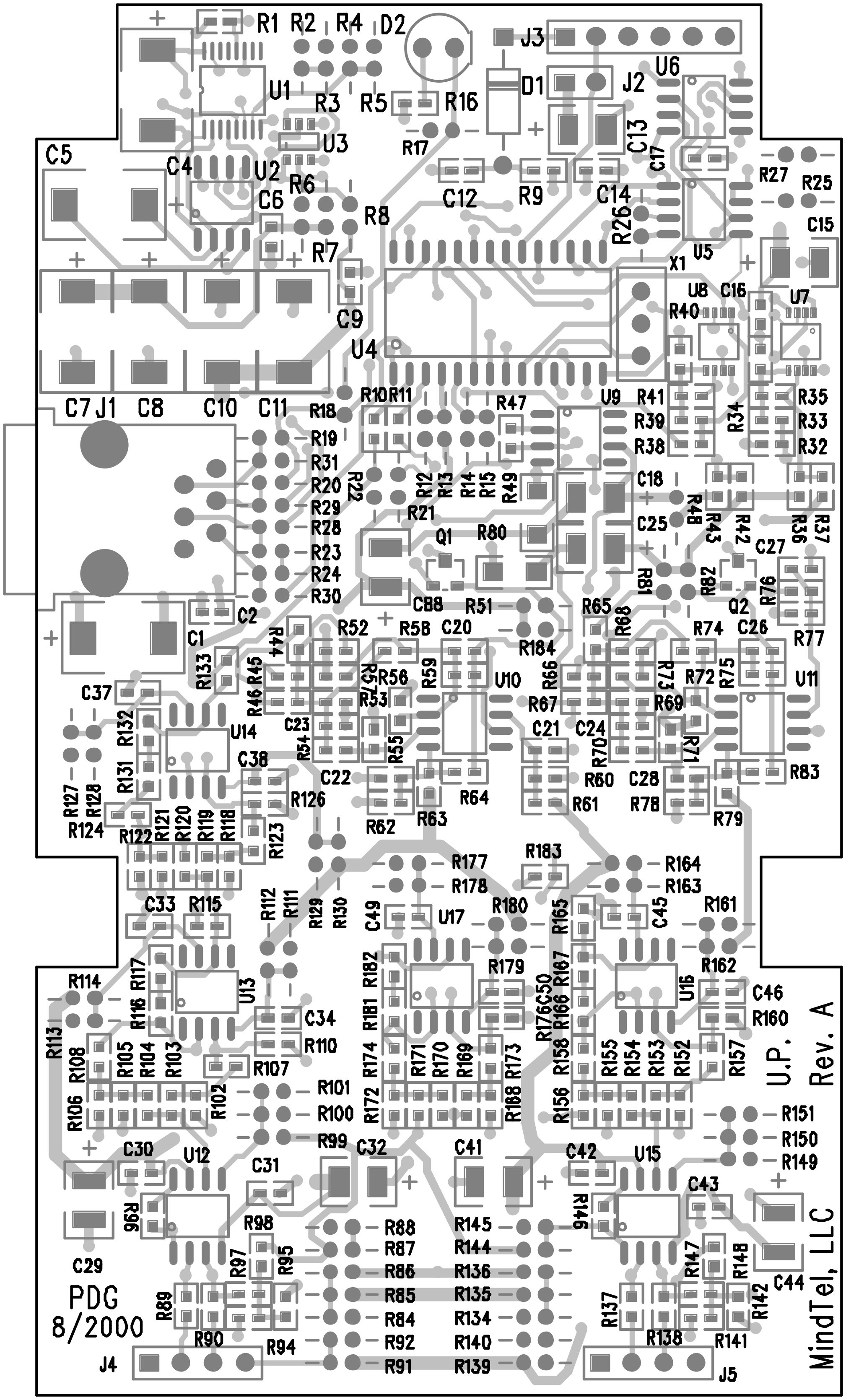


Photodiode (left) and multi-IR Led (right) Prototypes

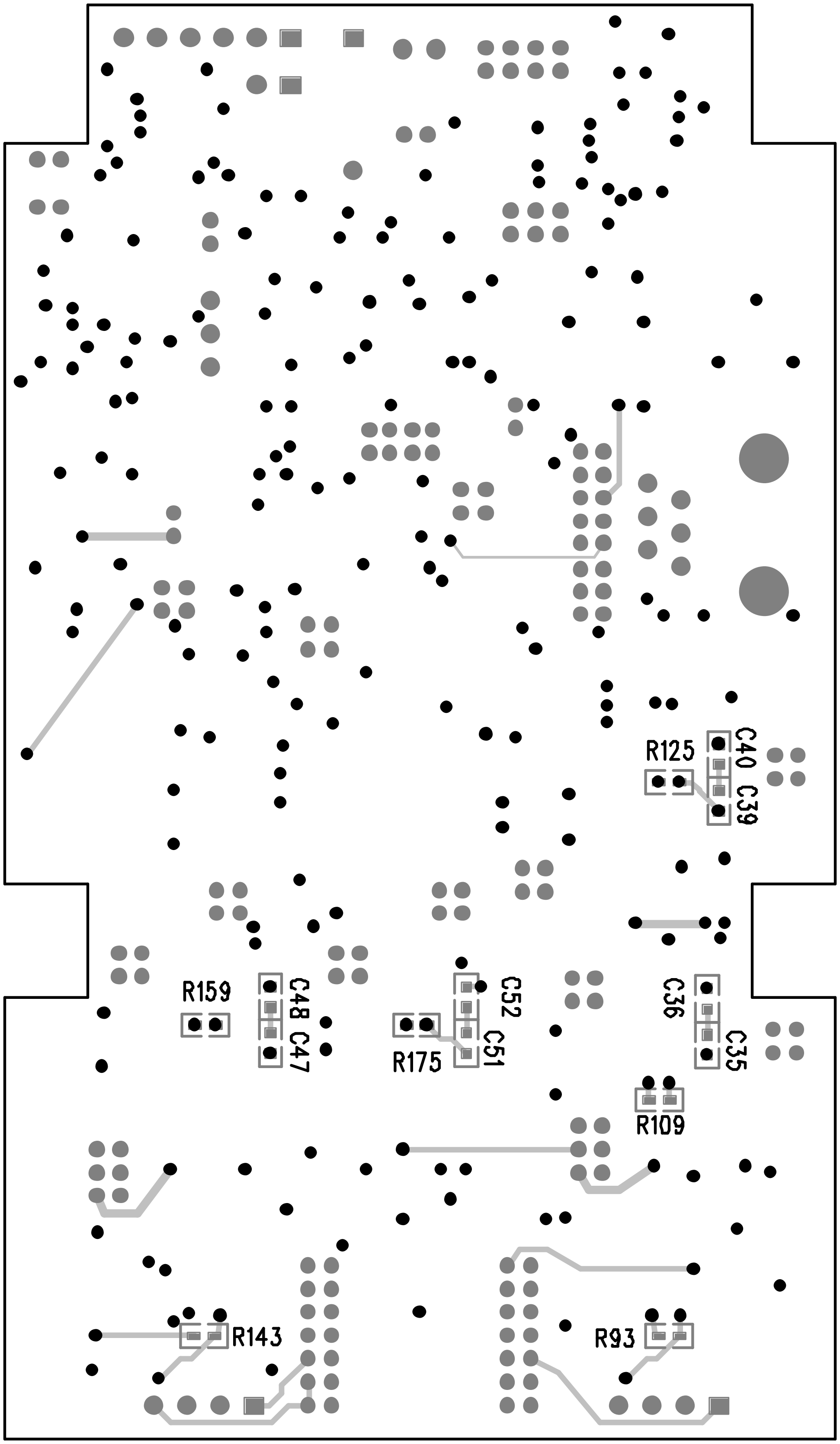


4-Channel DAC (switch mounts on side of enclosure; white wires implement changes required for the microcontroller to act alternatively as SPI master or slave).

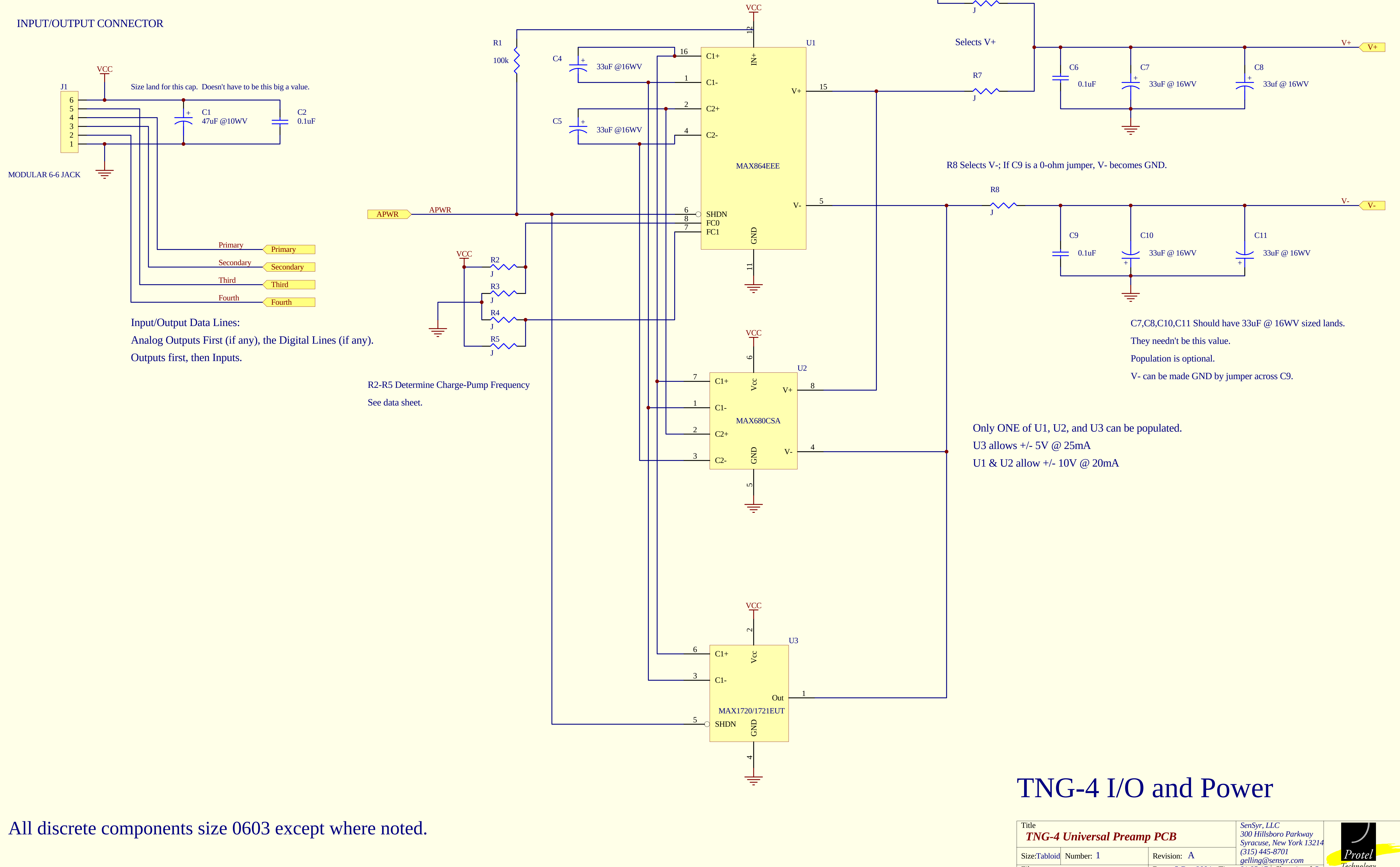
Appendix A1: UPP Top-side Component Layout



Appendix A2: UPP Top-side Component Layout



Appendix A3


INPUT/OUTPUT CONNECTOR
J1
MODULAR 6-6 JACK
VCC
Size land for this cap. Doesn't have to be this big a value.
C1
47uF @10WV
C2
0.1uF
Primary
Secondary
Third
Fourth
Input/Output Data Lines:
Analog Outputs First (if any), the Digital Lines (if any).
Outputs first, then Inputs.
APWR
R1
100k
C4
33uF @16WV
C5
33uF @16WV
R2
R3
R4
R5
R2-R5 Determine Charge-Pump Frequency
See data sheet.
U1
MAX864EEE
C1+
C1-
C2+
C2-
IN+
V+
V-
SHDN
FC0
FC1
GND
U2
MAX680CSA
Vcc
U3
MAX1720/1721EUT
Out
R6
R7
Selects V+
C6
0.1uF
C7
33uF @ 16WV
C8
33uf @ 16WV
R8 Selects V-; If C9 is a 0-ohm jumper, V- becomes GND.
R8
C9
0.1uF
C10
33uF @ 16WV
C11
33uF @ 16WV
C7,C8,C10,C11 Should have 33uF @ 16WV sized lands.
They needn't be this value.
Population is optional.
V- can be made GND by jumper across C9.
Only ONE of U1, U2, and U3 can be populated.
U3 allows +/- 5V @ 25mA
U1 & U2 allow +/- 10V @ 20mA
TNG-4 I/O and Power
All discrete components size 0603 except where noted.
Title
TNG-4 Universal Preamp PCB
Size: Tabloid
Number: 1
Revision: A
File:
Date: 5-Dec-2004
Time: 01:05:17
Sheet 1 of 5
SenSyr, LLC
300 Hillsboro Parkway
Syracuse, New York 13214
(315) 445-8701
gelling@sensyr.com
Protel Technology

Appendix A4

R32 and R38 connect DAC's to outputs.

R33/R34 or R33/R35, and R39/R40 or R39/R41 establish DAC gain.

R36 or R37, and R42 or R43 select DAC reference.

R28-R31 allow digital lines to be connected to TNG-4 I/O lines.

R25-R27 select certain memory chip options.

Inputs can go to A/D or to CCP inputs.

CCP lines can be inputs or outputs.

CCP lines can be attached to different I/O connector lines.

PIC 16C773 can provide limited VREFH AND VREFL.

PIC16C73 can use VREFH as input reference.

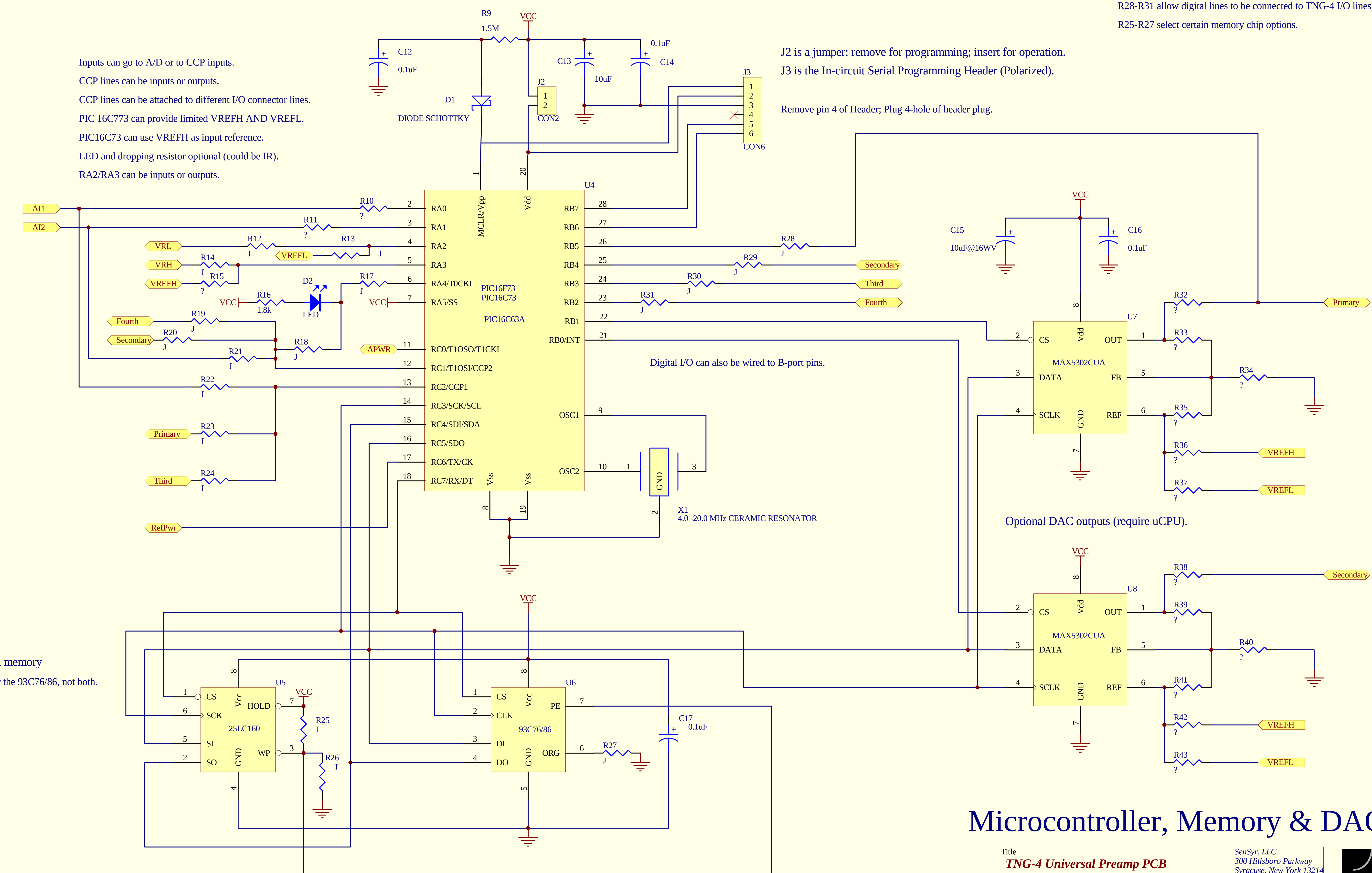
LED and dropping resistor optional (could be IR).

RA2/RA3 can be inputs or outputs.

J2 is a jumper: remove for programming; insert for operation.

J3 is the In-circuit Serial Programming Header (Polarized).

Remove pin 4 of Header; Plug 4-hole of header plug.



Optional EEPROM memory

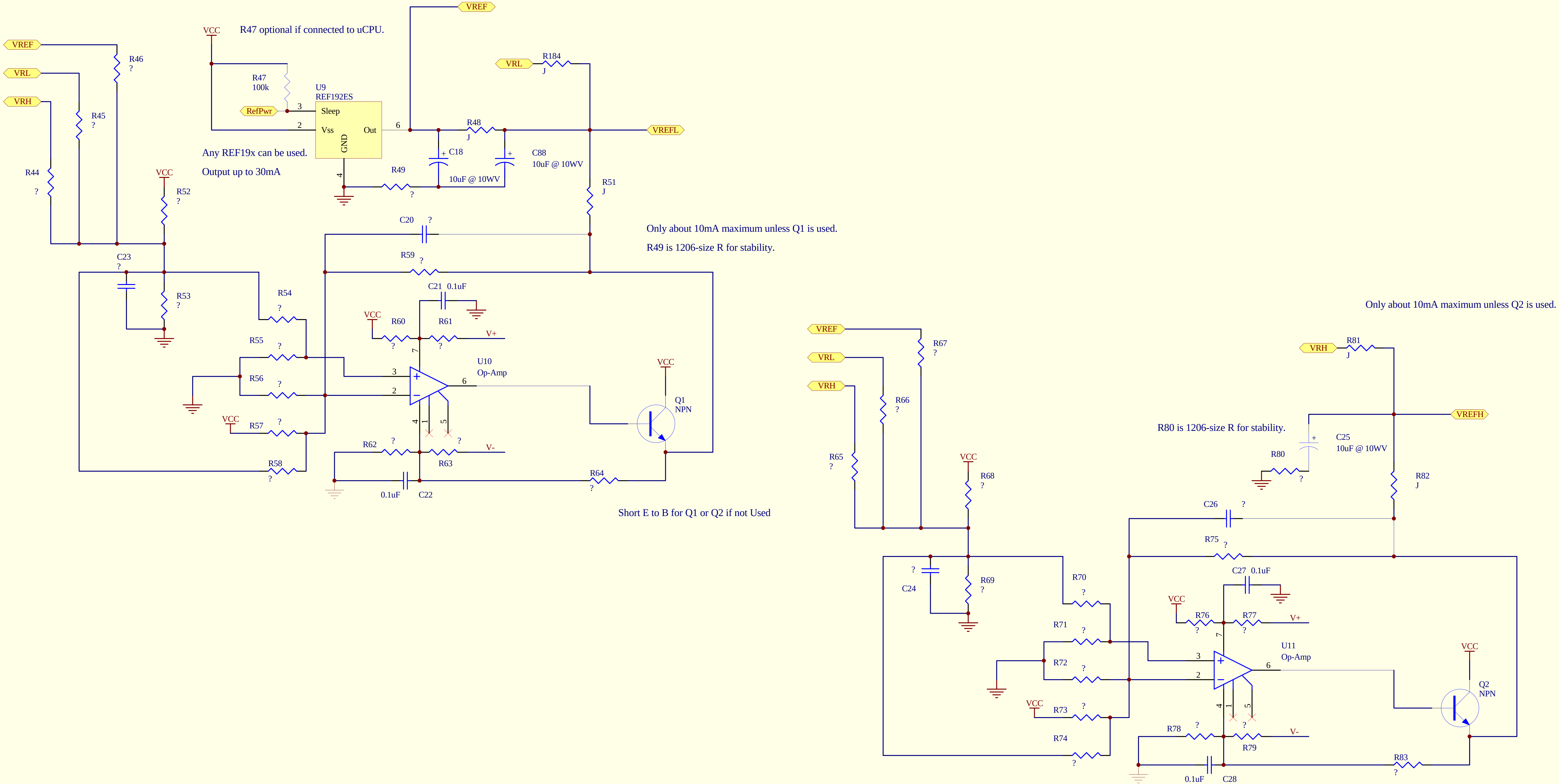
Either the 25LC160 or the 93C76/86, not both.

Up to 2k bytes.

Microcontroller, Memory & DACs

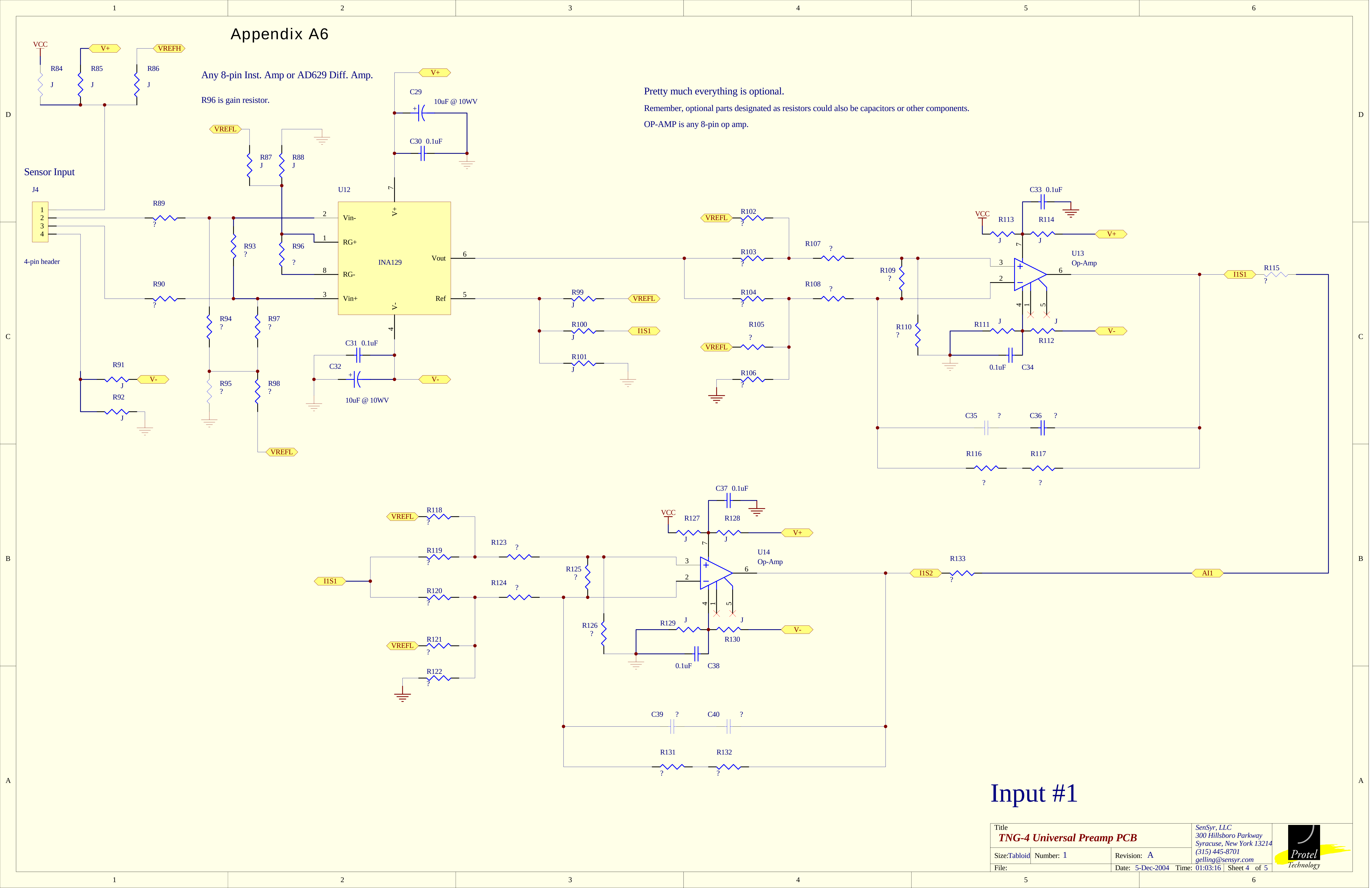
Title: *TNG-4 Universal Preamp PCB*			*SenSyr, LLC* *300 Hillsboro Parkway* *Syracuse, New York 13214* *(315) 445-8701* *gelling@sensyr.com*
Size: Tabloid	Number: 1	Revision: A	
File:		Date: 5-Dec-2004 Time: 01:06:44 Sheet 2 of 5	

Appendix A5



Reference Voltage(s)

Title: *TNG-4 Universal Preamp PCB*		*SenSyr, LLC* *300 Hillsboro Parkway* *Syracuse, New York 13214* *(315) 445-8701* *gelling@sensyr.com*
Size: Tabloid	Number: 1	Revision: A
File:	Date: 5-Dec-2004	Time: 01:03:46 Sheet 3 of 5


Appendix A6
Any 8-pin Inst. Amp or AD629 Diff. Amp.
R96 is gain resistor.
Pretty much everything is optional.
Remember, optional parts designated as resistors could also be capacitors or other components.
OP-AMP is any 8-pin op amp.
Sensor Input
J4
4-pin header
U12
INA129
Vin-
RG+
RG-
Vin+
Vout
Ref
V+
V-
VCC
VREFH
VREFL
10uF @ 10WV
C29
C30 0.1uF
C31 0.1uF
C32
U13
Op-Amp
U14
Op-Amp
I1S1
I1S2
AI1
C33 0.1uF
C34
C35
C36
C37 0.1uF
C38
C39
C40
Input #1
Title
TNG-4 Universal Preamp PCB
Size: Tabloid
Number: 1
Revision: A
File:
Date: 5-Dec-2004
Time: 01:03:16
Sheet 4 of 5
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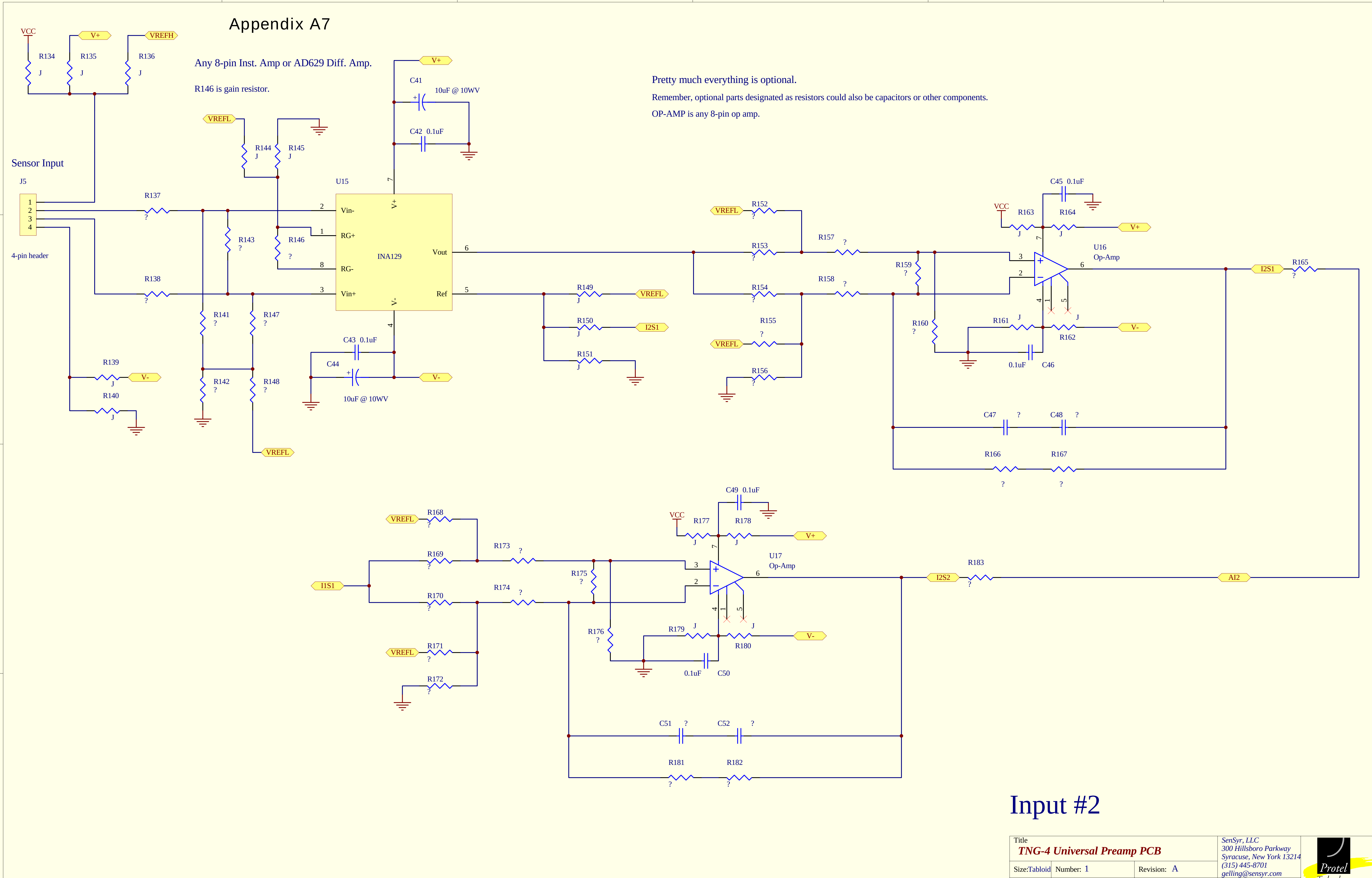
Appendix A7
Any 8-pin Inst. Amp or AD629 Diff. Amp.
R146 is gain resistor.
Pretty much everything is optional.
Remember, optional parts designated as resistors could also be capacitors or other components.
OP-AMP is any 8-pin op amp.
Sensor Input
J5
4-pin header
U15
INA129
Vin-
RG+
RG-
Vin+
Vout
Ref
V+
V-
C41 10uF @ 10WV
C42 0.1uF
C43 0.1uF
C44 10uF @ 10WV
VCC
V+
V-
VREFH
VREFL
R134 J
R135 J
R136 J
R137 ?
R138 ?
R139 J
R140 J
R141 ?
R142 ?
R143 ?
R144 J
R145 J
R146 ?
R147 ?
R148 ?
R149 J
R150 J
R151 J
I2S1
U16
Op-Amp
R152 ?
R153 ?
R154 ?
R155 ?
R156 ?
R157 ?
R158 ?
R159 ?
R160 ?
R161 J
R162 J
R163 J
R164 J
R165 ?
C45 0.1uF
C46 0.1uF
C47 ?
C48 ?
R166 ?
R167 ?
U17
Op-Amp
I1S1
I2S2
AI2
R168 ?
R169 ?
R170 ?
R171 ?
R172 ?
R173 ?
R174 ?
R175 ?
R176 ?
R177 J
R178 J
R179 J
R180 J
R181 ?
R182 ?
R183 ?
C49 0.1uF
C50 0.1uF
C51 ?
C52 ?
Input #2
Title
TNG-4 Universal Preamp PCB
Size: Tabloid
Number: 1
Revision: A
File:
Date: 5-Dec-2004
Time: 01:02:16
Sheet 5 of 5
SenSyr, LLC
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