The Pot Box mark II

Instructions for building an analog IC chip tester

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1 History

The Pot Box was originally described in a paper by Lloyd Watts of the California Institute of Technology. The Pot Box is used as an aid in the testing of analog integrated circuit chips, especially in regards to Analog VLSI as conceived by Carver Mead *et al.* The Pot Box mark II is a second-generation design created by the author of this technical note, and is meant to improve various aspects of the original Pot Box as well as prepare for the future mark III design, which will (probably) incorporate computer interfacing.

2 Pot Box features and their uses

Analog VLSI technology typically necessitates the availability of numerous set voltage sources for biasing transistors into the subthreshold region. Also, as for any analog technology, the testing is performed using oscilloscopes, function generators, and multimeters, all of which require standard BNC connections. The Pot Box mark II meets these needs by providing the following features (see Figures 4 and 6 for referenced part numbers):

- ZIF sockets for two standard chip packages used by MOSIS (40-pin DIP for the Tiny-Chip layout 16, and 84-pin PGA for the second smallest chip size 17). Labels denote how pin 1 of the DIP package and pin A1 of the PGA package are oriented.

- Power supply input allowing for both the standard ($V_{dd} > GND$) and reverse ($V_{dd} < GND$) conventions, with a phono-style jack 12 for +9V DC input from a standard DC wall-socket adapter which provides a steady +5V source to the entire box. An unregulated BNC input is available for all other values of V_{dd}. Ground is always tied to the chassis frame 1. A two-color LED 21 signals red for the standard and green for the reverse V_{dd}/GND conventions. When power is supplied through the phono jack, setting the power switch to "PHONO" provides power to the chip, and setting the power switch to "BNC" turns power off. When power is supplied through the BNC jack, the reverse is true: setting the power switch to "BNC" provides power to the chip, and setting the power switch to "PHONO" turns power off. If this behavior is not desired, a separate power switch may be installed for power ON/OFF in addition to the BNC/PHONO select.

- One V_{dd} and GND breadboard bus strip 15. This is located close to one of the two pinout protoboards 14b, allowing easy access to all of the chip pins.

- One standard breadboard for off-chip circuitry (13).
- Ten variable high-precision voltage sources varying between power and ground. These sources are made available using ten-turn potentiometers (3) having their two fixed ends tied directly to power and ground, and the other pin connected to the protoboard (14a) through a switch; the switches allow each source to be isolated from the chip for an accurate voltage reading from the multimeter port. The potentiometers are controlled by ten-turn dials (4), so the value on the dial is twice that of the output voltage when the power supply used is +5V. The dials can be locked to prevent accidental variance.
- A multimeter port which can be selected for reading any of the voltage sources (positions 1 through 10), the power supply (position 12), or a generic breadboard connection (position 11, not marked). This breadboard connection can be found on the input/output protoboard (14d).
- Input/output ports in the form of eight regular BNC connections (8), two isolated BNC connections (9), two triaxial connections (10), and the multimeter port (either BNC or banana plug connection (11)). All of these signals are available through the input/output protoboard (14d).
- Breadboard connections for all of the voltage sources, connectors, and pinouts from the sockets for easy configuration with 22-gauge wire jumpers. Pinouts from the two sockets are available on both sides of the box, on protoboards (14b) and (14c). Generally, jumpers are connected between (14a) and (14b) in order to connect the voltage sources to the chip, between boards (14b) and (15) to supply power and ground to the chip, and between (14c) and (14d) in order to connect the chip to the various inputs and outputs.

3 The mark II model

The changes made in the mark II model to overcome limitations of the original Pot Box are listed below:

- Dual sockets to accomodate the 84-pin PGA chip style as well as the usual 40-pin DIP package.
- Multimeter port select to prevent tying multiple voltage sources to the output port. Switches are used instead to isolate the voltage source from the chip for a more accurate measurement.
- 9V DC phono-plug and voltage regulator for wall socket power supply. BNC input remains for any power supply other than +5V.
- Banana sockets as well as a BNC jack for the multimeter port.
- Informative labeling.
- Copper ground planes for noise reduction.

4 Parts list

Item	Qty.	Src.	Part #	Cost Per	Total
1 Aluminum Chassis $10 \times 12 \times 3$"	1	EE	BUD AC 413	17.26	17.26
2 Aluminum Plate 10×12"	1	PH	T5052-.050	4.75	4.75
3 5K 10-turn Potentiometers	10	EE	Bourns 3540S-1-5K	9.39	93.90
4 10-turn dials	10	EE	Bourns H-507-6	8.72	87.20
5 12-position rotary switch	1	RS	275-1385	1.39	1.39
6 Knob	1	EE	Alcoswitch PKX-60B-1/4	1.66	1.66
7 SPDT toggle switch	11	EE	Alcoswitch MTA106DPC	3.44	37.84
8 Panel BNC jack	10	EE	Amphenol 554-91/2701	2.95	29.50
9 Panel isolated BNC jack	2	EE	Amphenol 554-90/2229	1.83	3.67
10 Panel triaxial jack	2	TI	1964-1-9	7.85	15.70
11 Panel banana jack	2	EE	108-0901-001	.25	.52
12 Panel phono jack	1	EE	Caltronics PJ-20	.94	.94
13 Breadboard (standard)	1	EE	3M Super-Strip	13.08	13.08
14 Protoboard (64×5 with pins)	6	TK	0203-0034	4.32	25.92
15 Protoboard (2×40 bus)	2	TK	(QT47B) 102-1047	2.50	5.00
16 ZIF socket, 40 pin DIP	1	FR	ZIF-40-AR	9.99	9.99
17 ZIF socket, 84 pin PGA	1	RM	2-0084-06512-190	13.89	13.89
18 Wire-wrap socket, 40 pin DIP	1	FR	40-6556-31	8.99	8.99
19 Wire-wrap socket, 84 pin PGA	1	FR	??	10.00	10.00
20 +5V DC voltage regulator	1	EE	LM340T-5V/7805	.80	.80
21 T–1–3/4 Bicolor LED	1	RS	276-012	1.19	1.19
22 470 Ω resistor	1	EE	NA	.10	.10
23 1 μF capacitor	2	EE	NA	.10	.20
24 Border tape	as needed	HW	NA	2.00/roll	.25
25 Dry-transfer lettering	as needed	EE	Datak 9671	14.55/pkg	1.00
26 Flat black enamel paint	1 can	HW	NA	2.99	2.99
27 Copper tape (2 inch width)	3 feet	PH	NA	15.00/roll	1.00
28 Screws (4–40, 1/4" long)	9	HW	NA	1.29/pkg	.40
29 Hex nuts (4–40)	9	HW	NA	1.29/pkg	.28
30 Epoxy resin glue	as needed	HW	NA	2.23	2.23
31 Wire (26 gauge)	as needed	FR	SO26	3.00/roll	1.00
32 Wire-wrap wire	as needed	EE	30 AWG 50ft.	5.00/roll	8.00
33 Foam-rubber feet	4	HW	NA	.12	.50

Pot Box total cost .... $ 402.94

5 Source Listing

Suppliers (abbreviations from table, page 3):

HW: Any nearby hardware store
RS: Any nearby Radio Shack
EE: Stanford Electrical Engineering supply store
PH: Stanford Physics supply store
TI: Time Electronics (Kings supplier) (408) 734–9888
RM: Robin & Mulvin & Co. (3M supplier) (800) 666–1081
FR: Fry's Electronics, Palo Alto (415) 496–6000
TK: Toolkit Specialists (Global Specialties supplier) (408) 745–6020

Manufacturers of specialty parts:

Global Specialties (protoboard brand products)
70 Fulton Terrace, P.O. Box 1942
New Haven, CT 06512
(203) 624–3103, (800) 345–6251
FAX (203) 468–0060

3M Corporation (84 pin PGA sockets)
P.O. Box 2963
Austin, TX 78769

Bourns (precision potentiometers and dials)
1200 Columbia Ave.
Riverside, CA 92507
(714) 781–5500

Kings (cable connectors, BNC and triaxial)

6 Assembly Instructions

1. Buy all materials listed to make sure that measurements for cutting and drilling the chassis box will be correct.

2. Prepare the protoboard-with-pins 14 as shown in Figure 1. I used a Dremel Moto-tool with a thin sawblade to cut the plastic. Size requirements on the 12" length chassis means that one of the protoboards 14b has to be cut lengthwise, getting rid of the half without connectors. A slightly longer chassis would help. An 84-pin protoboard is made by the following steps:

   (a) Remove backing from protoboard (it's only black electrical tape).

   (b) Remove the 25th pin clip (they can be simply pulled out).

   (c) Saw the protoboard through the 25th row.

(d) File the shorter section back to the 24th row.

(e) The 24-row board will be placed next to a 60-row board on the chassis to make an 84-row protoboard. Fill gaps with white RTV silcone or some plastic filler.

(f) Repeat to make four 84-row sections in all. One 60-row section makes two 24-row sections. The result looks best and fits more tightly if the sawed end of the board faces inward against the other protoboard.

3. Prepare the protoboard bus strip (15) as shown in Figure 2. Shorten the buses by sawing off close to the pins, being careful not to hit the metal strips underneath. This allows two buses to be abutted, extending the full width of the chassis without protruding over the sides. A wider chassis will also do the trick. At the abutting ends of the two buses, peel back the adhesive backing to expose the metal strips. Peel it back far enough that the strips can be soldered to, but not so far that they will contact the metal of the chassis around the hole (see Figure 3).

4. Arrange protoboards, sockets, and dials on chassis to check fit. Make any needed adjustments to the protoboards or drilling diagram.

5. Cut bottom panel (2) to match the box (10×12 inches) if necessary, and round off the corners with a file.

6. Cut and drill chassis box as shown in Figures 3 and 5. Square holes can be milled out or drilled at one end and sawed through with a power saw. Note that alignment-tab holes are meant to keep the switches and dials from turning in their holes, and should always be measured from the center of the main bore. Generally, alignment-tab bores need only be drilled partially through the chassis from underneath. File all rough edges smooth, and clean out all metal dust. Insert connectors and switches to confirm proper sizings, then remove.

7. Clamp the base plate to the chassis, and drill eight holes through both plate and chassis simultaneously. Drop machine screws through the holes as you proceed to prevent misalignment.

8. Remove base plate and spray paint entire chassis, several coats (matte black recommended, using white lettering for labels).

9. Use dry-transfer lettering to label the box. You may want to wait until everything is installed in order to do this, but it's easiest if you label first, provided you keep track of where all the parts are going. Place all bordering tape that doesn't go on the protoboards. See Figures 4 and 6 for labeling (25).

10. Place ground-plane copper tape around the inside of the chassis and solder firmly to the chassis (you will need a very hot soldering iron to do this, in the range of 900 to 1000 degrees). Make sure that it reaches all the parts which require ground plane connections; this includes the outer shield of all the BNC and triax connectors, the bus strip, and the potentiometers.

11. Intall all parts! See Figures 4 and 6: Attach the ZIF sockets to the wire-wrap sockets. Use epoxy resin adhesive to glue down protoboard parts and chip wire-wrap sockets, and the LED (you may want to use an LED mounting bracket which can be glued to the chassis, with the LED inserted into the bracket). If you have a larger chassis and have not sawed through most of the protoboard screw-mount holes, you may want to drill extra holes through the chassis top and mount the protoboards that way, with flat-head machine screws. Make sure that the end pins on the protoboard-with-pins and the two exposed strips on the V_{dd}/GND bus do not touch the chassis metal. Make sure that potentiometers are turned fully counterclockwise and that dials are positioned on zero and locked when installing (note that installing the Bourns dials 4 requires a 1.5mm metric hex key (allen wrench) to install, which is very difficult to find. I used a filed-down 1/16" wrench).

12. Add pinout numbers to the bare half of each protoboard-with-pins section such that the numbers align correctly with the protoboard holes. Example pin-out labels are found in Figure 7. Mark the voltage supplies on protoboard 14a by extending the tape lines from the switches to the protoboard holes.

13. Wire the power supply as shown in Figure 8.

14. Wire the potentiometers and switches as shown in Figure 9. Adjust the knob on the rotary switch so labels match the switch position. The switches should connect the pots to the protoboard when in the upward position.

15. Wire the input/output connectors as shown in Figure 10. Check to make sure that the numbers on the protoboard label match up with the correct pins.

16. Wire wrap the 40-pin socket to the closest protoboards-with-pins 14b and 14c. Each pin of the socket will connect to each of the protoboards. Pin 1 of the socket connects to the third protoboard pin, and successive socket pins connect to odd-numbered protoboard pins, such that the connections are aligned with the labeling as seen in Figure 7. Use a wire color that can be differentiated easily from the wires on the 84-pin PGA socket.

17. Wire wrap the 84-pin socket to the closest protoboards-with-pins 14b and 14c. Each pin of the socket will connect to each of the protoboards, and protoboard pins will be shared with the 40-pin socket. Wire-wrap all of the protoboard pins so that the PGA pin letters (A1 through J11) align with the labeling as seen in Figure 7. I recommend a three-color wiring scheme, one color for each layer of pins starting at the outside and working inward. This makes it easier to tell wires apart.

18. Test for open circuits and shorts throughout.

19. Glue hex nuts behind holes in chassis box with epoxy. Test for a strong bond.

20. Place foam-rubber feet 33 on the bottom plate.

21. Screw bottom plate in place. Don't over-torque the screws. This completes the Pot Box project!

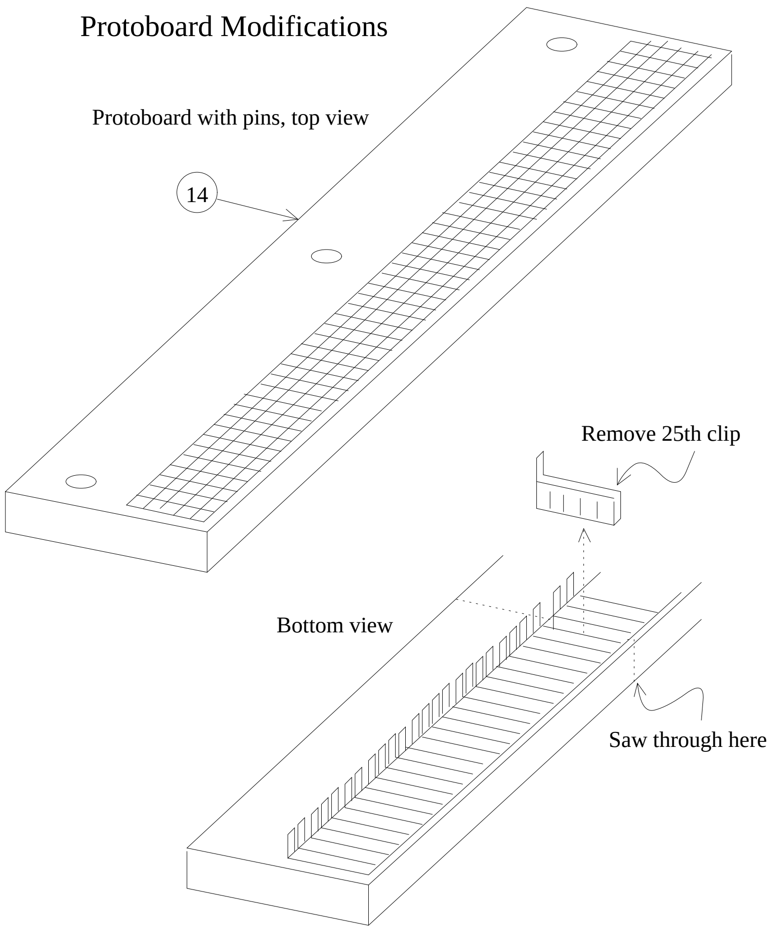

Figure 1: Modifications to the protoboard-with-pins.

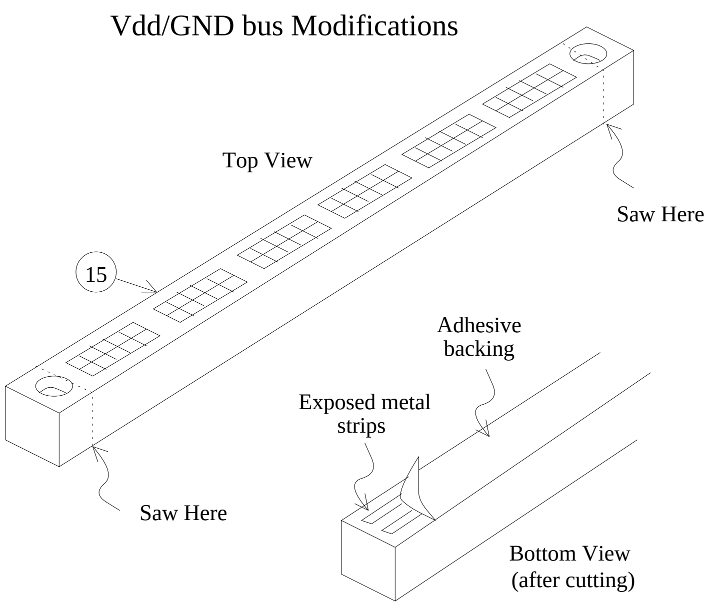

Figure 2: Modifications to the protoboard bus strip.

Pot Box blueprint, top view

Drafted by: Tim Edwards; Scale = 2/3; All units in inches

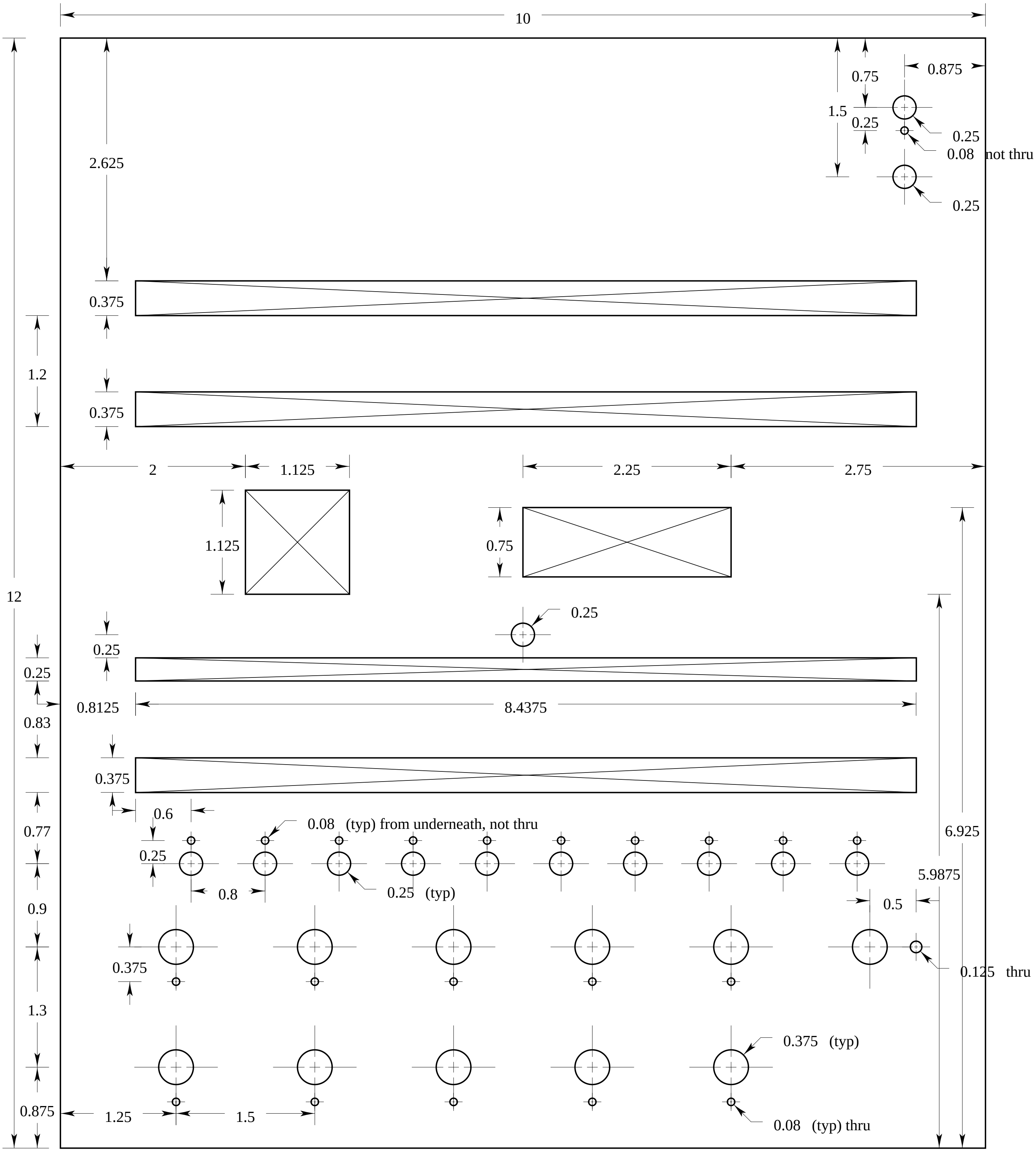

Figure 3: Cutting and drilling diagram for the pot box chassis top.

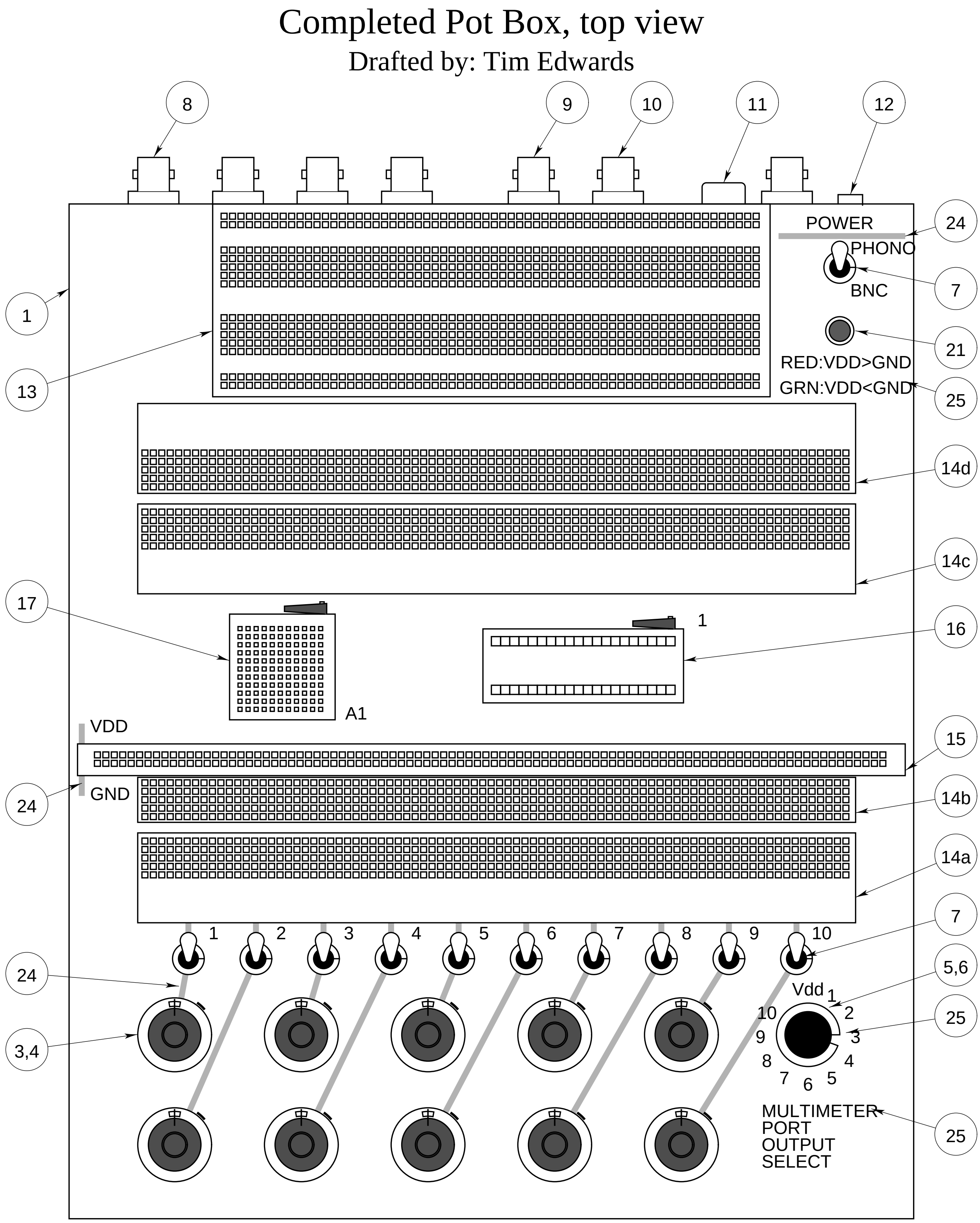
Completed Pot Box, top view
Drafted by: Tim Edwards
8
9
10
11
12
24
POWER
PHONO
7
BNC
1
13
21
RED:VDD>GND
GRN:VDD<GND
25
14d
14c
17
16
1
A1
VDD
15
24
GND
14b
14a
1
2
3
4
5
6
7
8
9
10
7
24
5,6
Vdd
1
2
3
4
5
6
7
8
9
10
25
3,4
MULTIMETER
PORT
OUTPUT
SELECT
25

Figure 4:

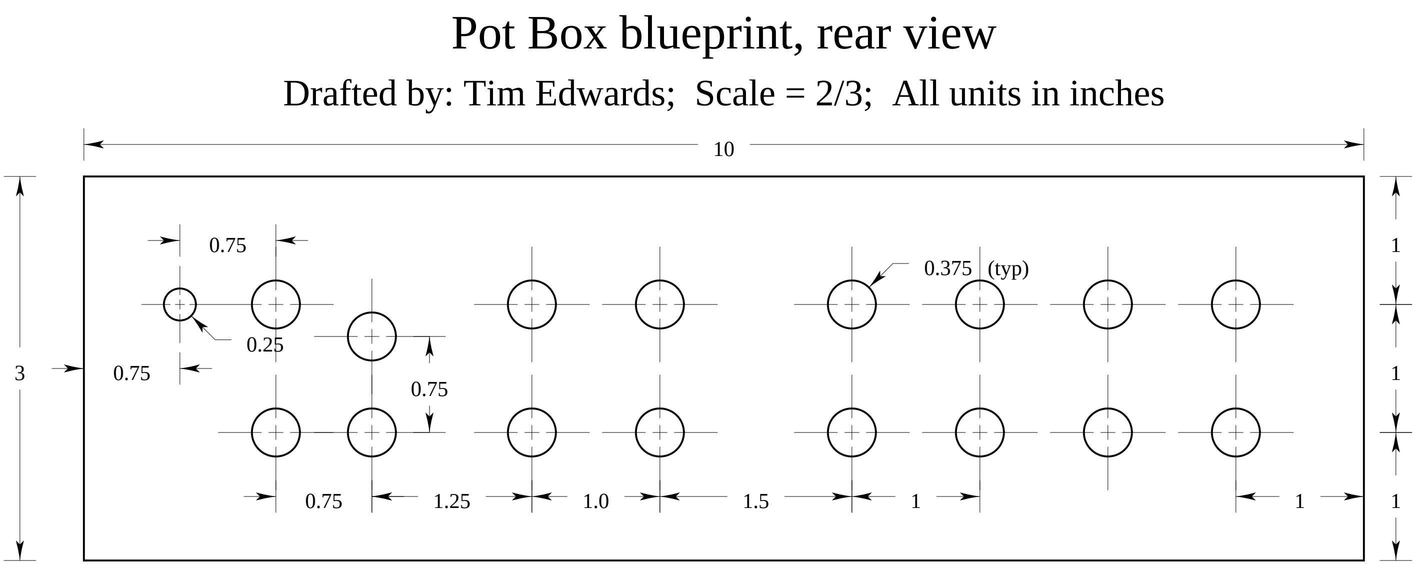

Figure 5: Drilling diagram for the pot box chassis end.

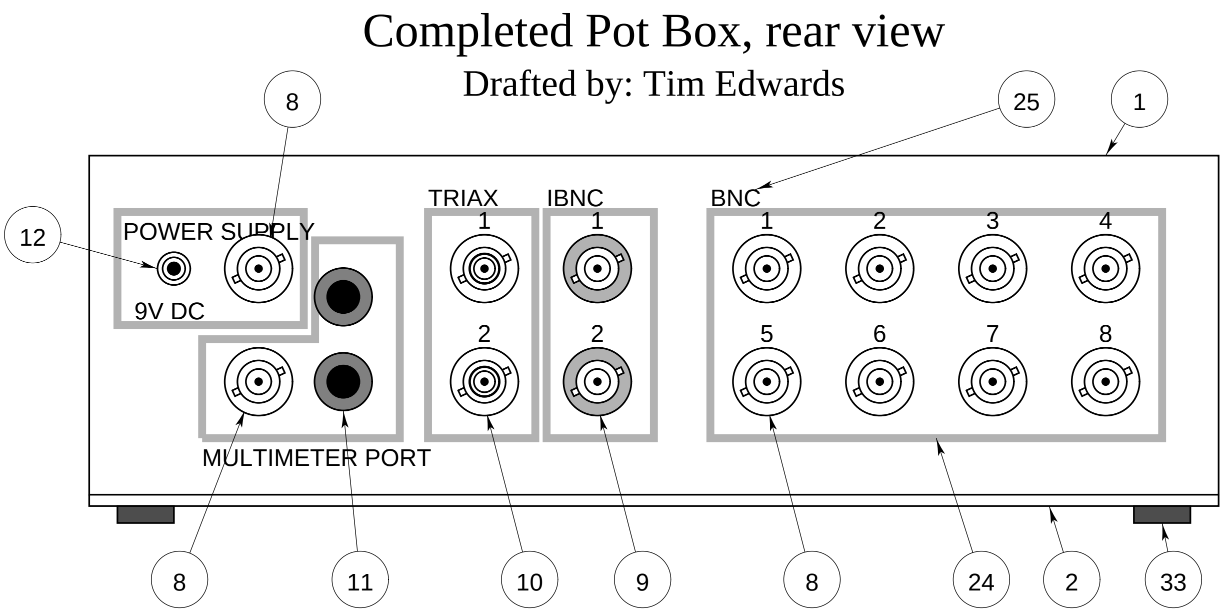

Figure 6:

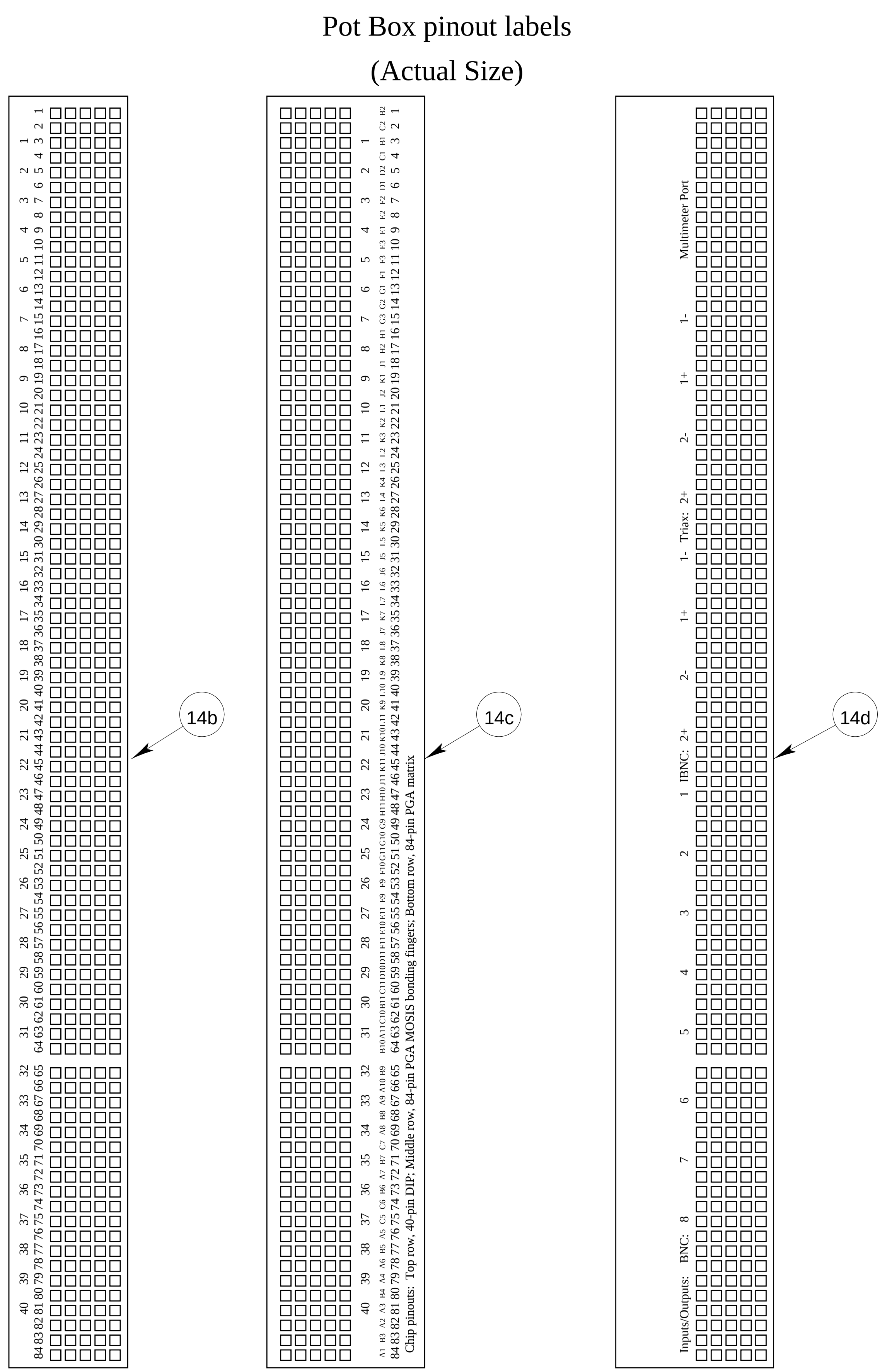

Figure 7: Full-scale samples of labels for ZIF socket pinouts.

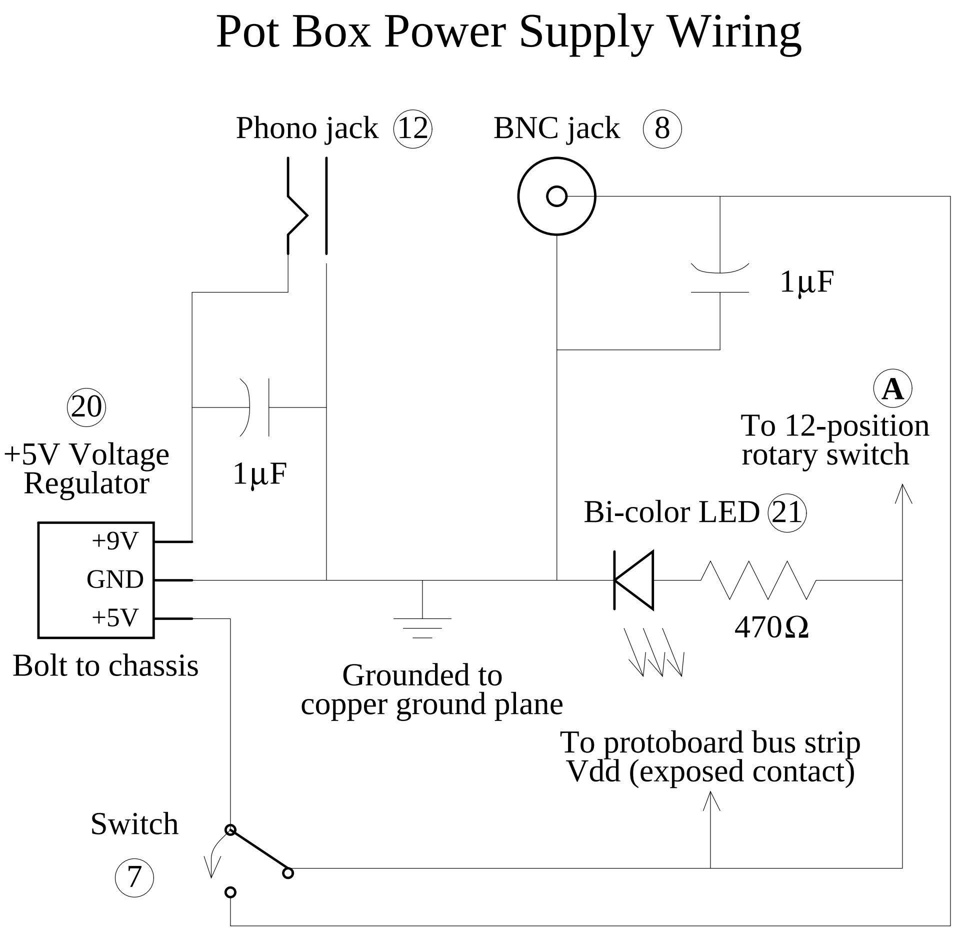

Figure 8: Wiring diagram for the power supply connections.

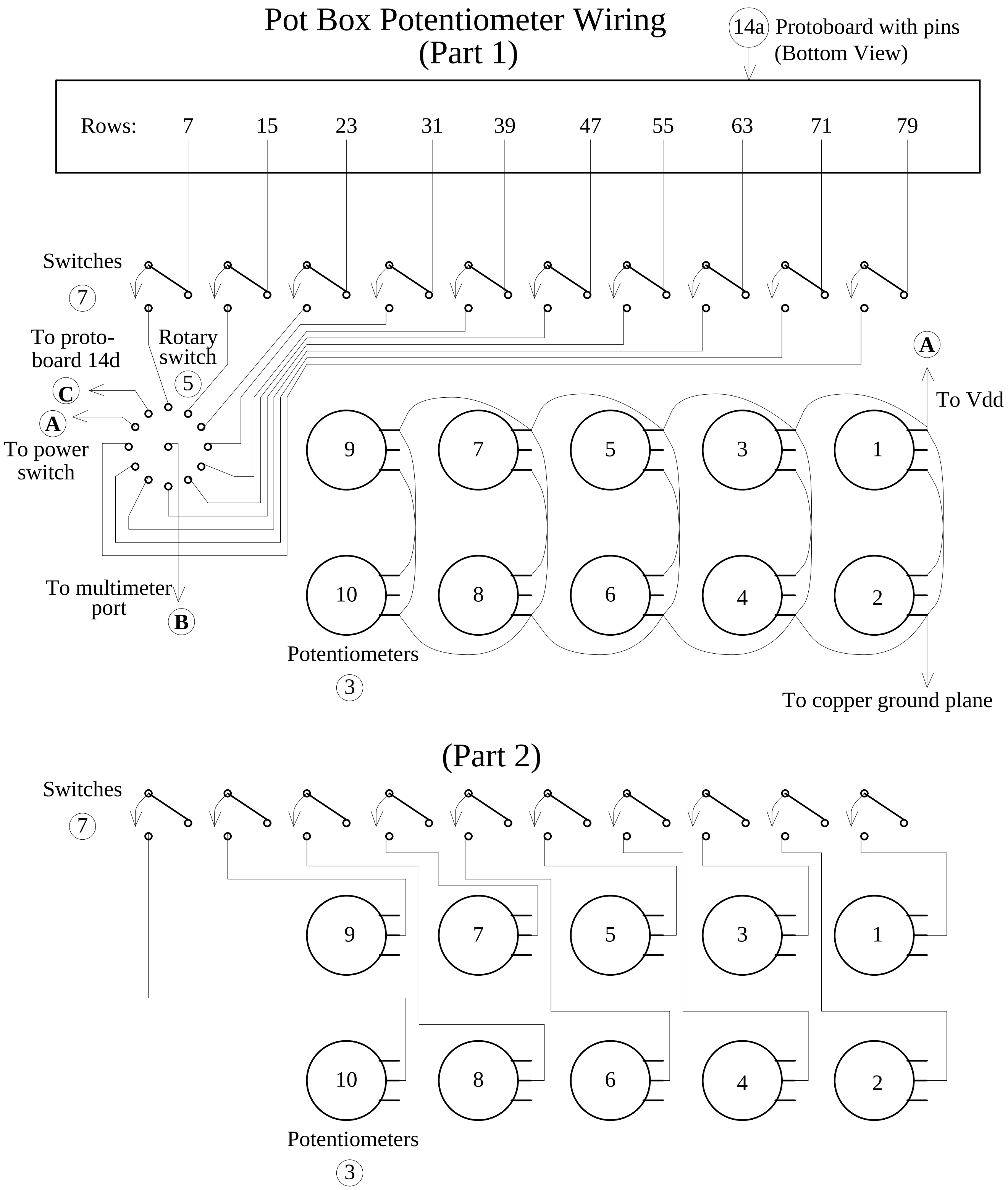

Figure 9: Wiring diagram for the potentiometers and switches.

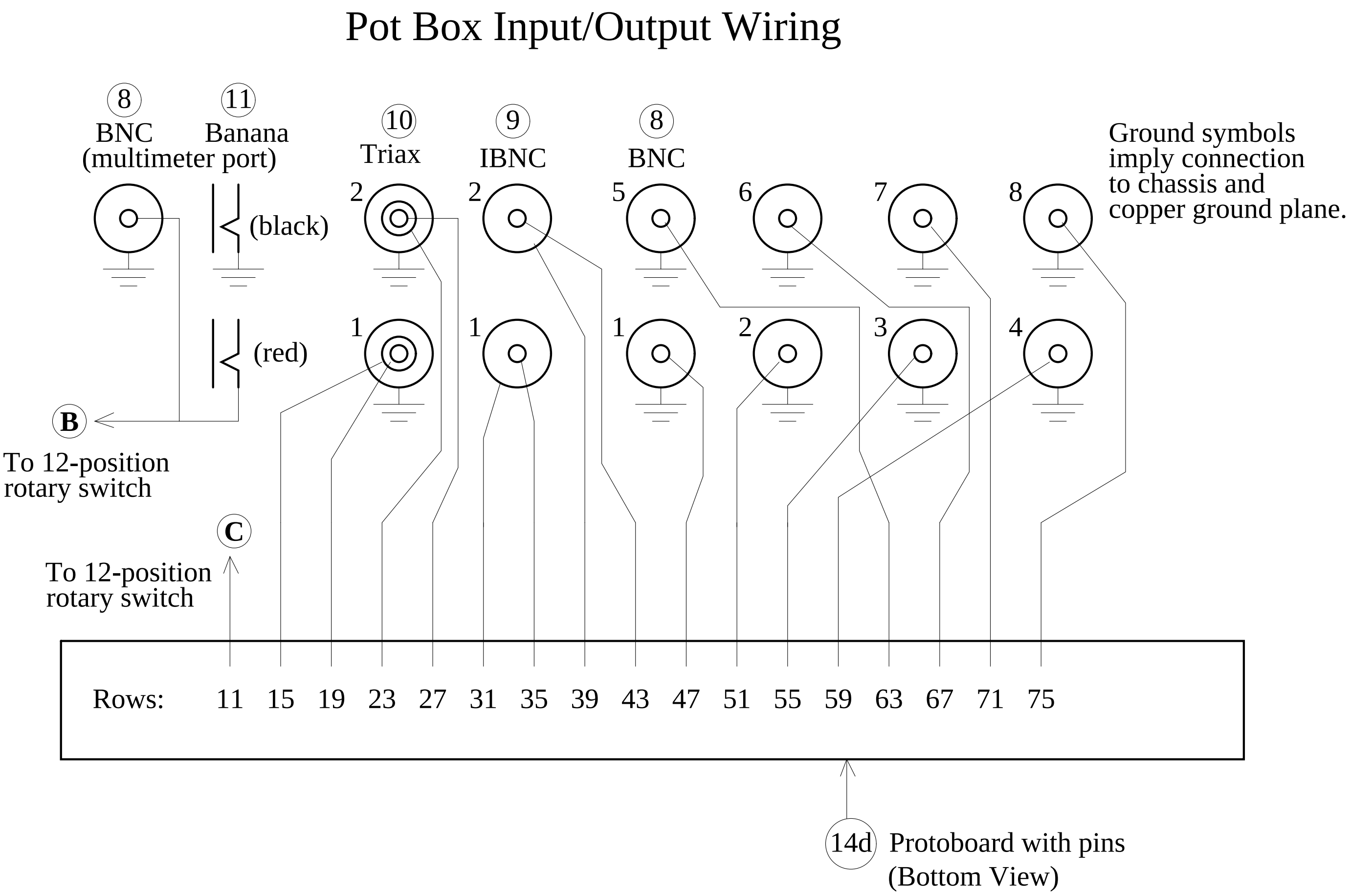

Figure 10: Wiring diagram for the input/output ports.

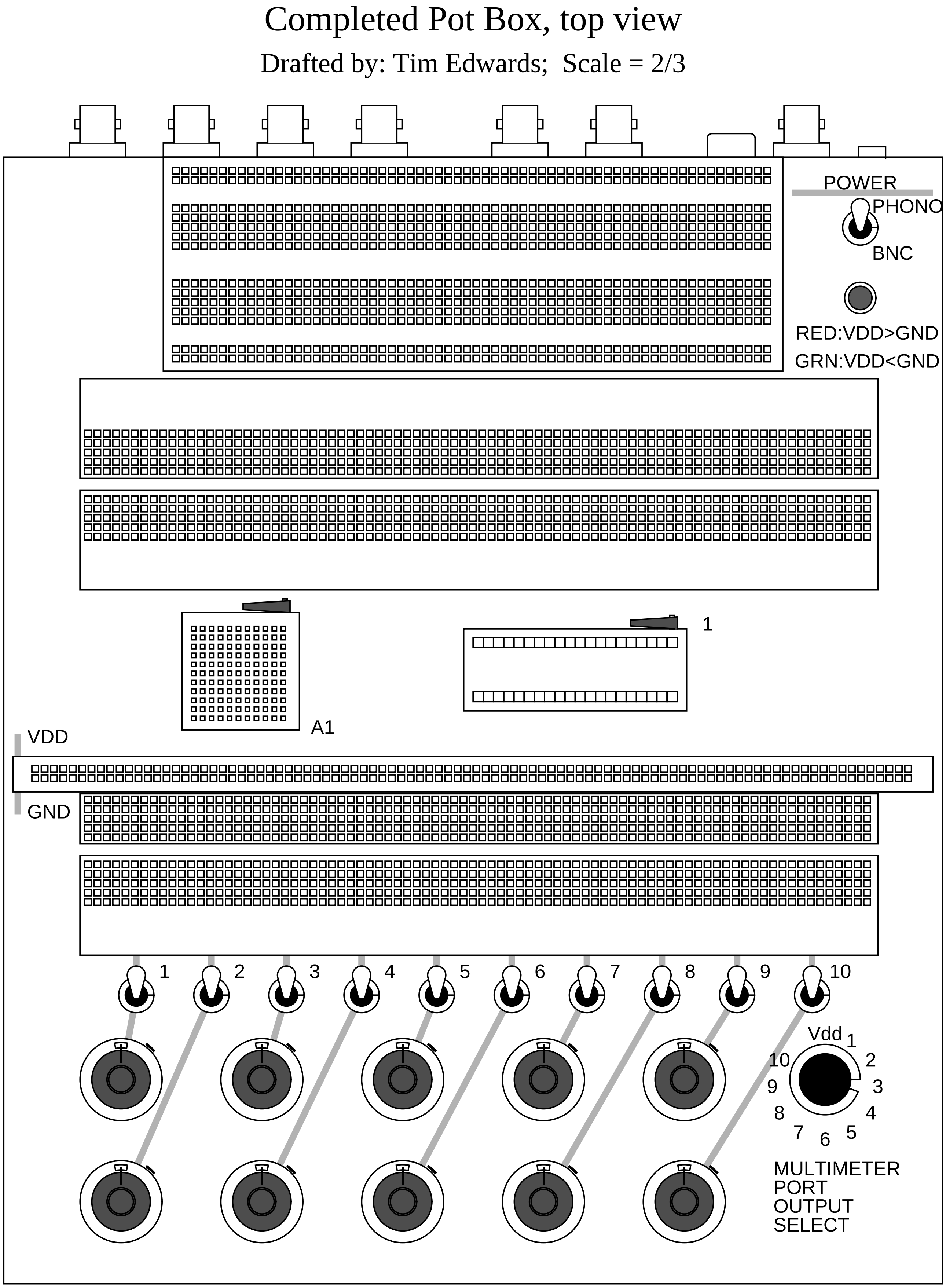

Figure 11: Drawing of completed Pot Box as seen from the top.

Completed Pot Box, rear view

Drafted by: Tim Edwards; Scale = 2/3

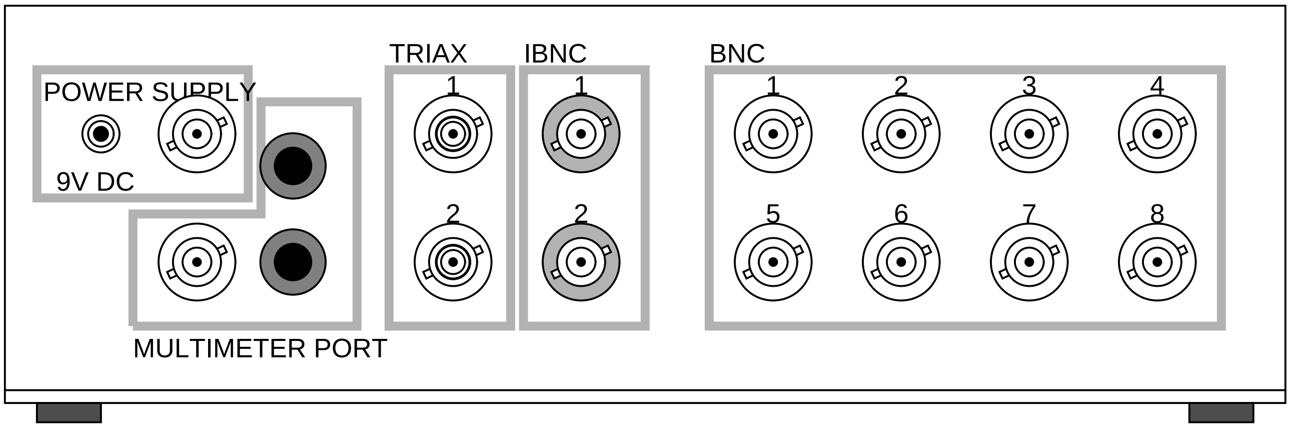

Figure 12: Drawing of completed Pot Box as seen from the end. Parts mounted on top are not shown.