The Grado RA-1 Clone

Les Carpenter G4CNH January 2024

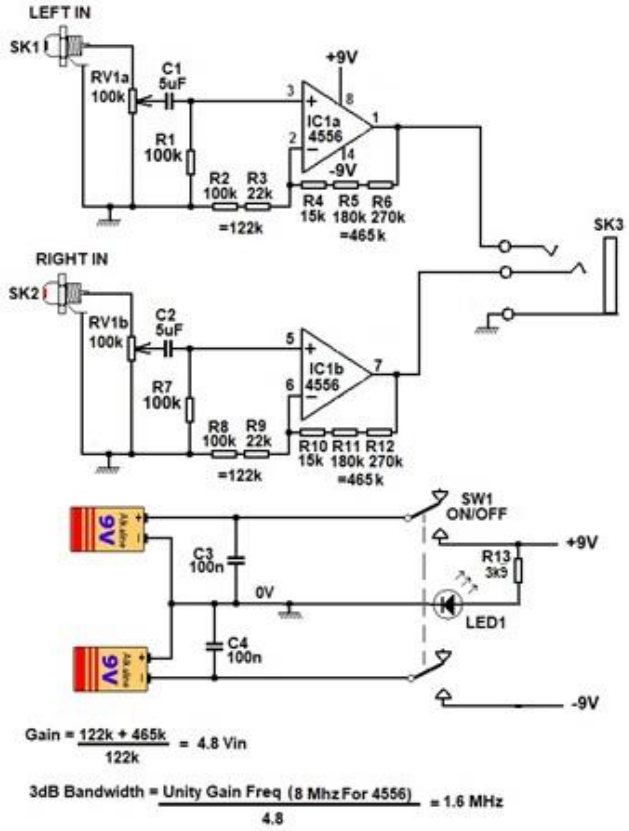
Contents

SPECIAL NOTICE: A Mk.2 version of this amplifier has been designed to allow connection of a remote power supply. Also shown is a typical power supply circuit and can be seen here :-

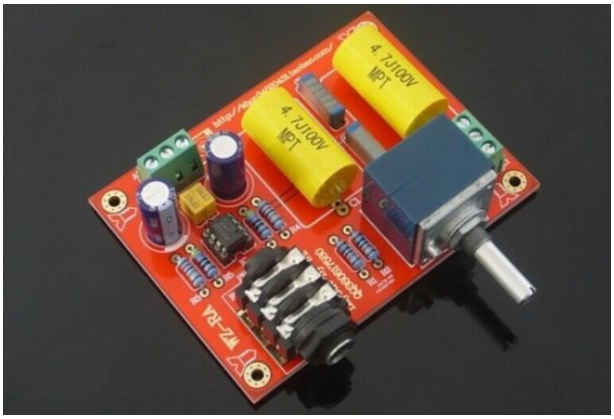
http://www.g4cnh.com/public/Mk_2_RA1_Headphone_Amplifier_Clone.pdf

Purpose of building the RA-1 Clone

The Clone was built to test out the viability of it driving various headphones and their impedances and to evaluate the circuit in general against its incredible high price!
Here is a typical clone circuit of the RA-1.



The 4556 operational amplifier is capable of driving up to 70mA which implies over 1 Watt into headphones of 228Ω but much less if the standard 8Ω ones are used. It certainly drives the Authors Grado SR80 and Audio Technica ATH-50X's well.
The circuit was first configured with multiple resistors to attain as close as possible to Grado's values but if we accept 2% tolerances then standard values can be used, with R2/R3 and R8/R9 made 120k and R4/R5/R6 and R10/R11/R12 made to 470k. They only set gain at around x4.8 (13.7dB) and not frequency! With main parts costing just £20, it is hard to see how the wooden case that Grado supply is worth an additional £300?



This eBay board does look an attractive board but then one has to add the battery clips and RCA Jacks to complete. Can we beat the lowest eBay price of around £30?

I doubt it if we include the case, always the most expensive part, but this would have to be bought for the eBay model too. Another thing is the battery clips that would require case opening each time you needed to change the batteries. The alternative and much favoured by the author, is the fitting of a dual Bulgin BX0026 PP3 unit, though this costs almost £15 after VAT. It does make the clone box look a little more professional.
I last fitted one of the single units in my Aircraft handlers test box and it worked a treat.
http://www.g4cnh.com/public/AIRCRAFT_HANDLERS_HEADSET_TEST_BOX_AND_TRAINING_AID.pdf

I am also thinking of using the same Takachi YM-200 case if everything will fit. OK it is a large case but I no longer go back packing but feel free to re-engineer into a small plastic case if you want to. The case I used has an electrical wholesaler price around £28 but on eBay it is priced at £75!
Buyer beware, there are sharks out there.

Technical Description

The audio circuit is identical for both channels so only the Left will be described but the Right channel components are shown in parenthesis.
Input from SK1 (SK2) is fed directly to the volume control RV1a (RV1b).
The wiper of the control is coupled via C1 (C2) to the circuit board input Pin A (D).
The Ground of SK1 (SK2) is connected to the volume control RV1a (RV1b) and then routed to the circuit board input Pin B (E).
R1 (R4) serves as Ground leak for IC1a (IC1b) Operational amplifier, type 4556 with up to 70mA drive capability.
Gain of the op-amp is set by R2 (R5) and R3 (R6) which should be approximately 4.8 times Vin or +13.7dB.
Instrumentation shows a gain of approximately 13.7 dB so no problems there.
The calculated frequency where the Op-Amp gain reduces to 1 is approximately 1.6 MHz.

Output from the Op-Amp at Pin 1 (7) is fed to PL5 Pin C (F) with Ground on two Pins marked G.

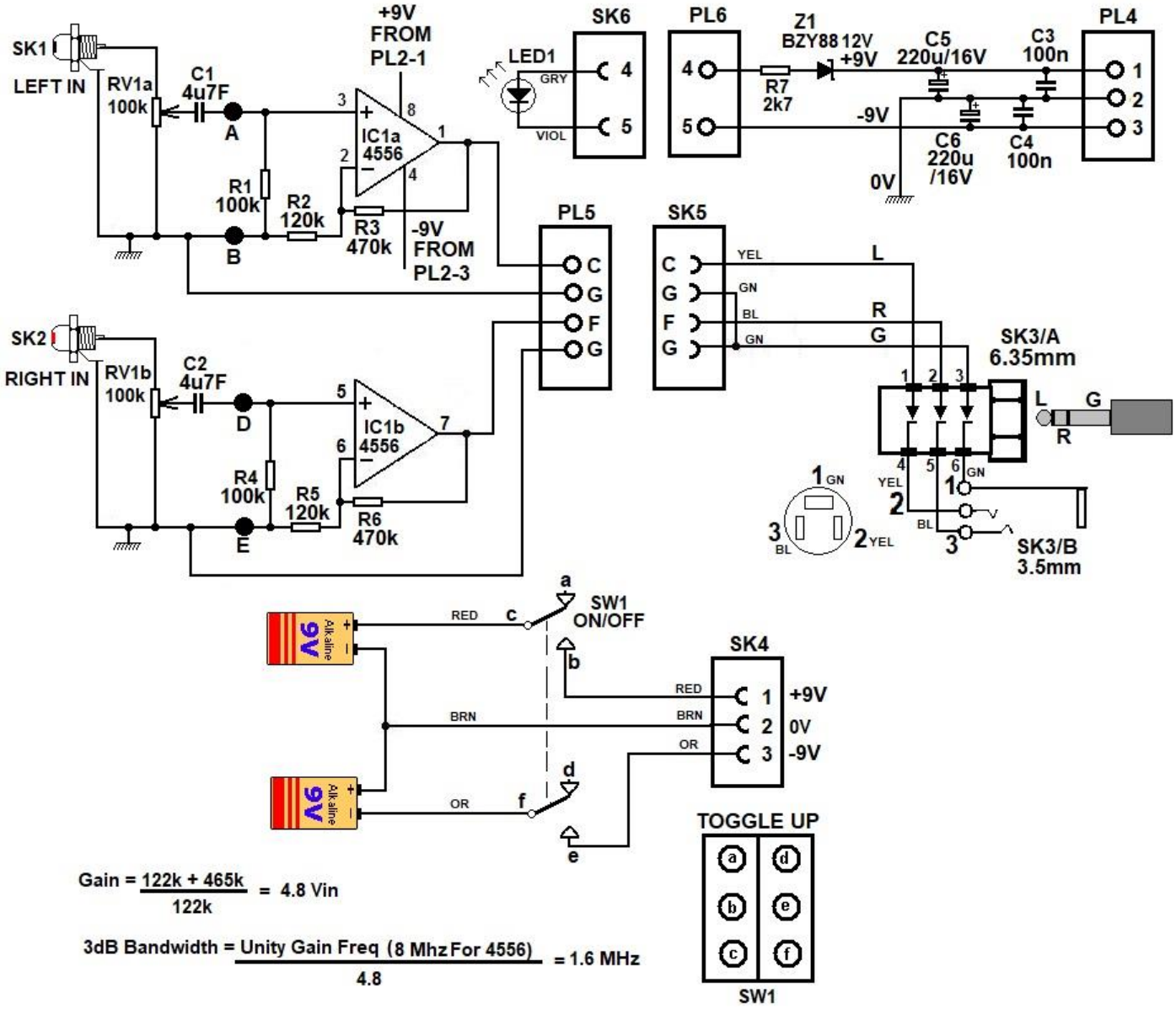
R7 is chosen for the particular LED being used as an ON indicator. In the adopted circuit (Page 4) it produced just over 1mA to provide adequate illumination of a High Brightness LED.
You may find it is too bright, even at this low current and increasing R7 will reduce the brilliance of the LED and also the very small current drain from the batteries.
The Zener Diode Z1 acts as a battery voltage monitor, allowing the LED to illuminate if the voltage present on its cathode is greater than 12V.
Output to the LED is via PL6, Pin 4 is LED Anode and Pin 5 is LED Cathode.
Note that both batteries are monitored so that the current drain is on both batteries rather than just one if the LED was powered from say just BT1.
Power to the board is via PL4, Pin 1 is +9V, Pin 2 is 0V and Pin 3 is -9V.
C3, C4, C5 and C6 are the usual supply decoupling capacitors.

User Instructions

If it is necessary to install or replace the batteries, then slightly lift the door on the battery compartments and pull the battery drawers out. Install the PP3 batteries, taking note of polarisation though the drawers have a mechanical safeguard to prevent incorrect insertion. Replace the drawers.

To apply power to the unit it is necessary to turn on the ON/OFF toggle switch to its up position, done this way as to help safeguard against inadvertent operation though a Front panel LED indicator is fitted for visual warning.
The LED will illuminate whilst the batteries are furnishing at least 6 Volts each.
Below this the LED will extinguish, reminding you that the batteries are close to replacement even though the unit will still be working.
A stereo headphone may be plugged into either the large quarter inch socket or the smaller 3.5mm so catering for the most common plug sizes. Because it is not recommended that two headsets with different plugs are used at the same time as this may over load the internal circuitry, inserting the larger jack plug removes signals to the smaller 3.5mm socket.

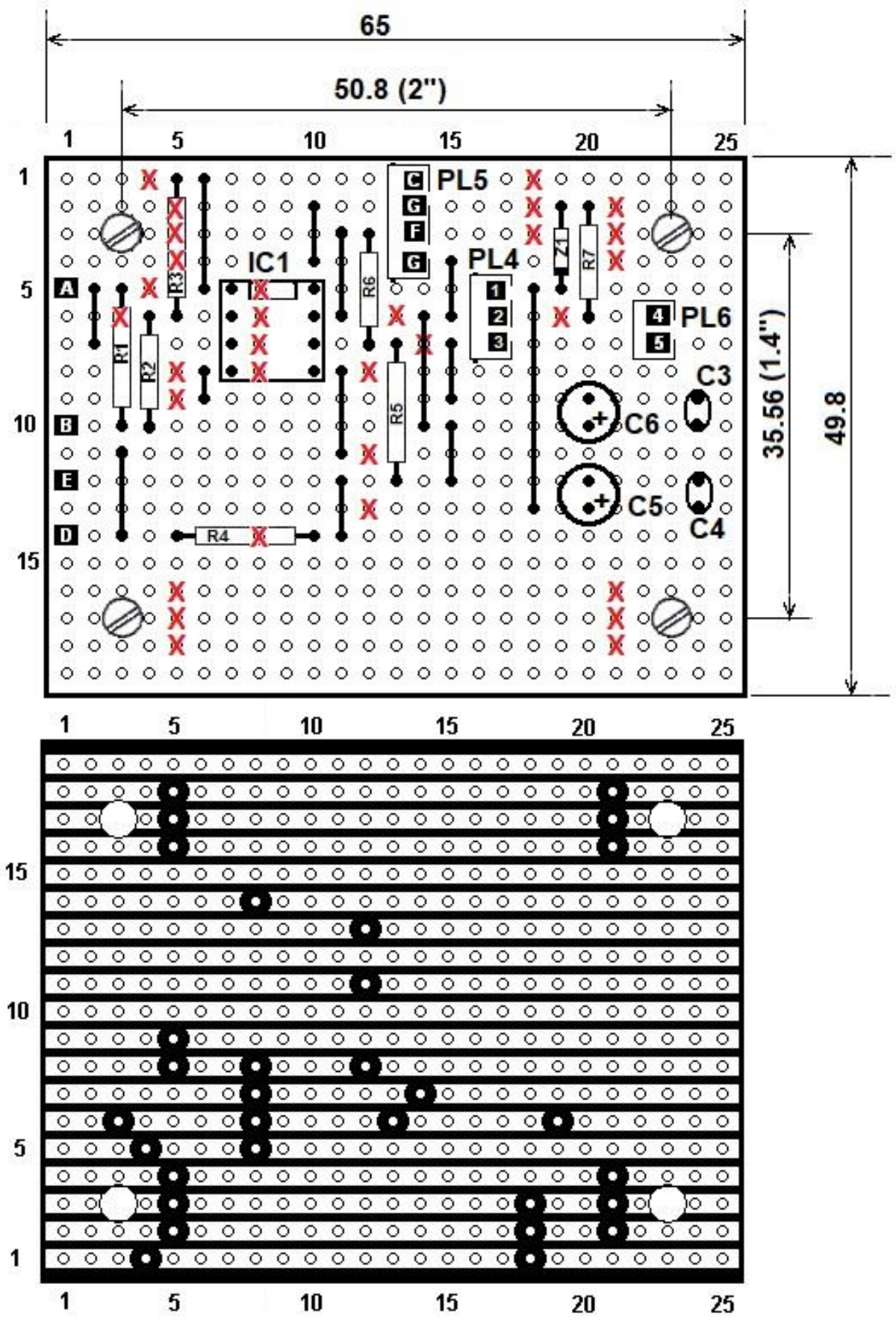
The circuit adopted



Typical labels

100%

Suggested strip board layout



Board Track cuts

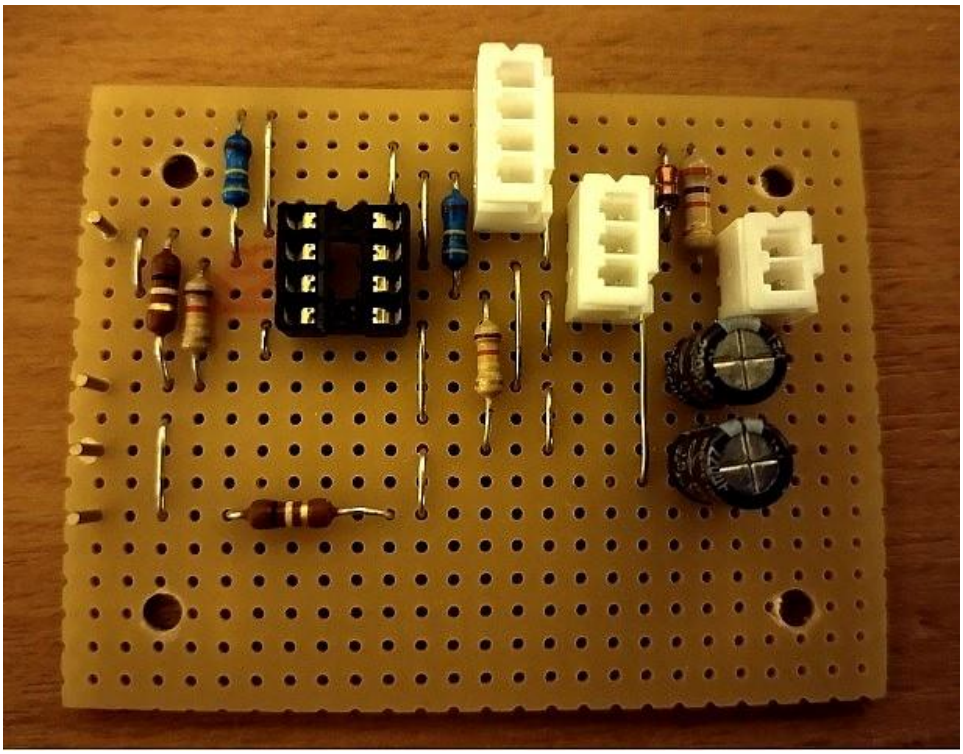
The stripboard used has 19 Tracks with 25 Holes per Track. It is 49.8mm (2.56”) x 65mm (4.76”).
The Fixing centres are 50.8mm (2”) x 106.68mm (4.2”). A table of Track/Hole cutting appears below and a 3M5 drill will be found OK for cutting the tracks if a proper track cutting tool is not available.
A good inspection is recommended afterwards to spot any non-breaks due to fine copper filaments on the cut extremities and also any swarf shorting to adjacent tracks.

Track cut table.

TRACK	HOLE CUT(S)	TRACK	HOLE CUT(S)	TRACK	HOLE CUT(S)
1	4, 18	8	5, 8, 12	15	No Cuts
2	5, 18, 21	9	5	16	5, 21
3	5, 18, 21	10	No Cuts	17	5, 21
4	5, 21	11	12	18	5, 21
5	4, 8	12	No Cuts	19	No Cuts
6	3, 8, 13, 19	13	12		
7	8, 14	14	8		**TOTAL 31**

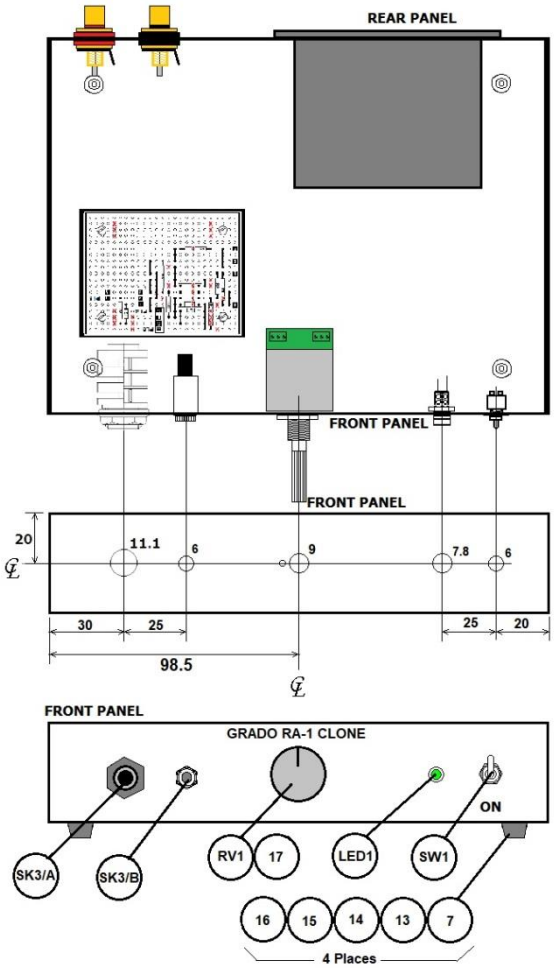
Wire Link Table

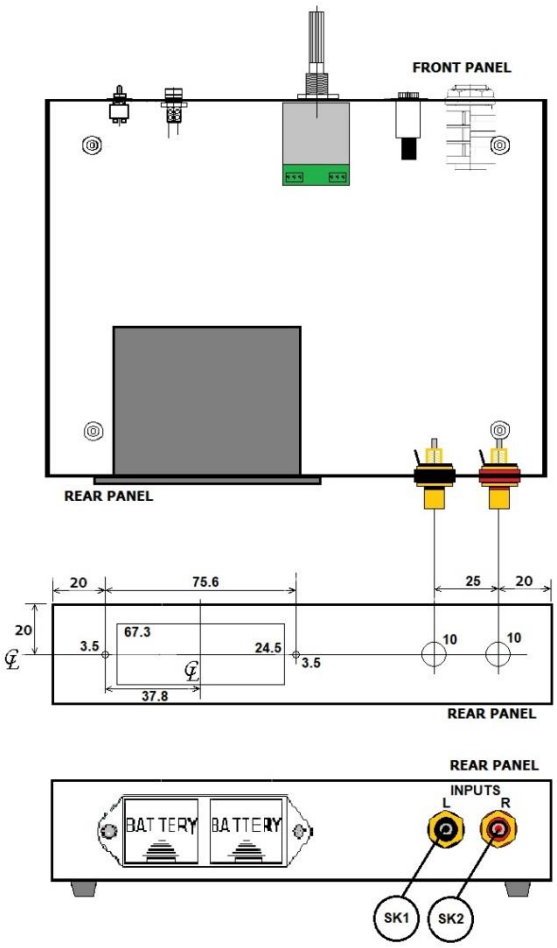
Link Size	Hole Number and Tracks Joined	
1 Pitch	H6 – T8 to T9.	(1 Total)
2 Pitches	H2– T5 to T7, H10 – T2 to T4, H11 – T12 to T14, H15 – T4 to T6.	(4 Total)
2 Pitches	H15 – T7 to T9, H15 – T10 to T12.	(2 Total)
3 Pitches	H3 – T11 to T14, H11 – T3 to T6, H11 – T8 to T11	(3 Total)
4 Pitches	H6 – T1 to T5, H14 – T6 to T10.	(2 Total)
9 Pitches	H18 – T5 to T13.	(1 Total)
	TOTAL LINKS 13	

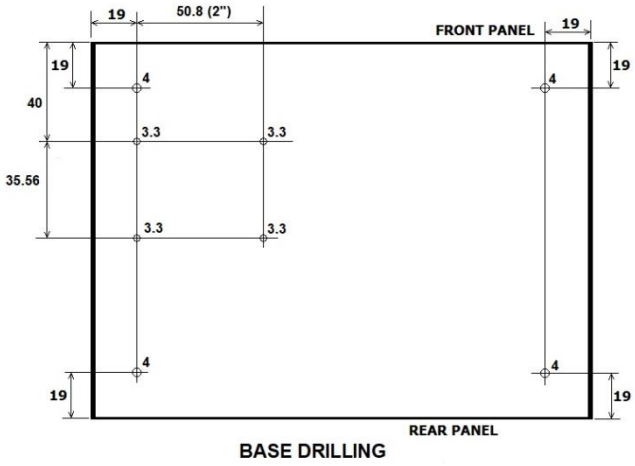


C3 and C4 not shown in above photograph as these were transferred from the battery box terminals later.
(See later view on Page 11 which also shows pre-made cables for SK4, SK5 and SK6).

Box Drilling and Assembly TBD







BASE DRILLING

RV1 AND PCB

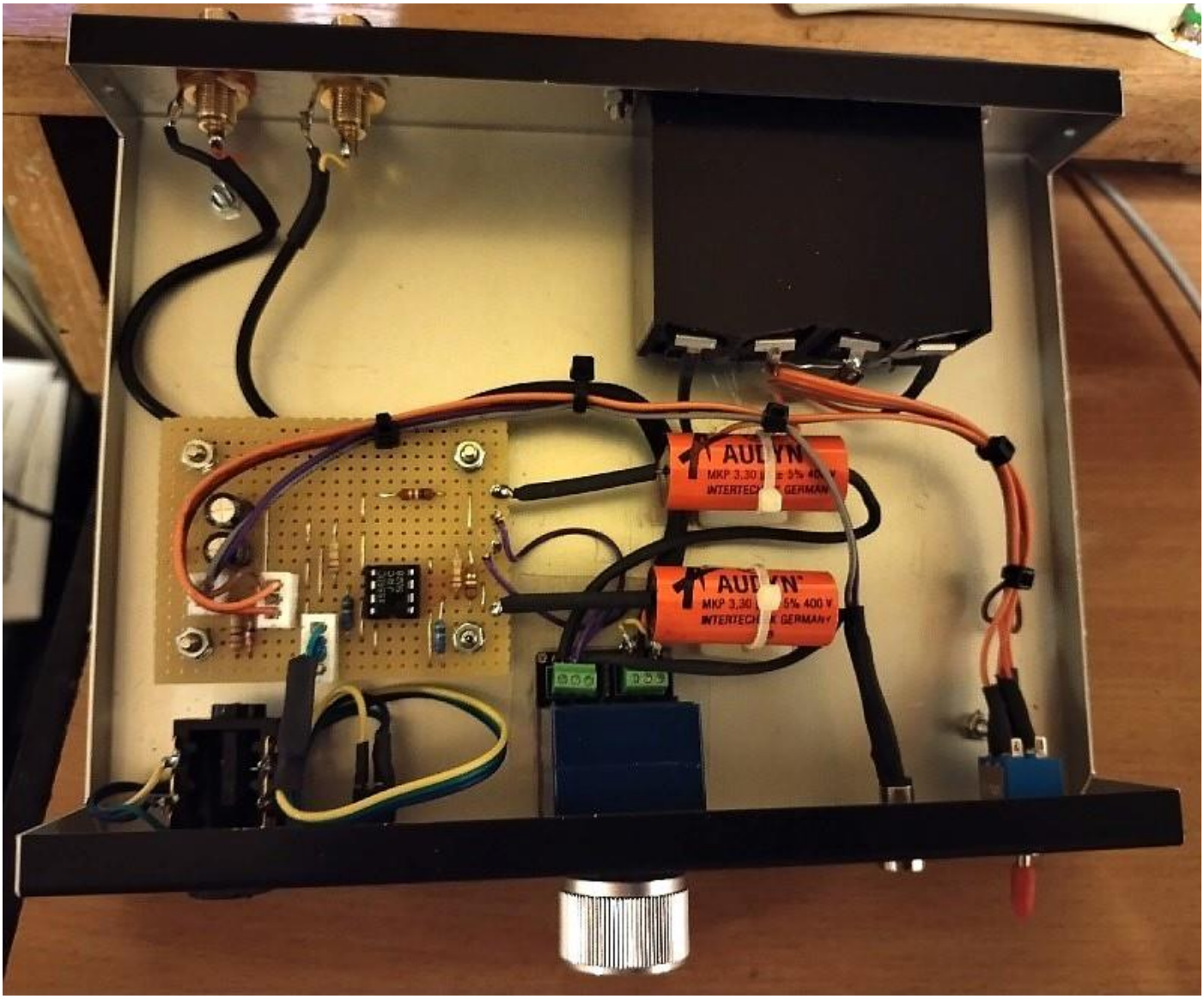
Parts List

Ref	Description	Makers Part	Supplier
1	Case	Takachi YM-200	RS 373-2277
2	Stripboard 19 Tracks x 25 Holes, 49.8mm x 65mm	Cut from 64 x 95 mm board	Cricklewood CQ64
3	24SWG Tinned Copper Wire for board links.		RS Components 355-085
4	LED, Ultra Bright Blue 5mm. Clear 7500mcd		Cricklewood B5U
5	LED Bezel 5mm. complete with 8mm retaining nut.		Cricklewood 5CC
6	Battery Box with dual drawers for PP3 Battery	Bulgin BX0026	RS Components 593-710
7	Rubber Foot, 4 off	19mm Diameter x 12.7mm High	Farnell 1876523
8	M3 x 6, Pan head	4 off for fixing Item 2	Internet for small quantity
9	M3 x 10 M-F Standoff Pillar	4 off for Item 2 mounting	Internet for small quantity
10	M3 x 12, csk head	4 off for fixing Item 6	Internet for small quantity
11	M3 shake proof Washer	4 off for fixing Item 6, 4 off for mounting Item 2	Internet for small quantity
12	M3 Nut	4 off for fixing Item 6, 4 off for mounting Item 2	Internet for small quantity
13	M4 x 16 cross head screw, (integrated shake proof)	4 off for fixing inside Item 7	Farnell 2770753
14	M4 Plain Washer	4 off for fixing inside Item 7	Farnell 1377537
15	M4 shake proof Washer	4 off for fixing Item 7 inside case	Farnell 7096483
16	M4 Nut	4 off for fixing Item 7 inside case	Farnell 1419449
17	22mm Knob, Aluminium to fit RV1		
PL4	3 Pole, Power connector, JST XH2.54mm	Optional – can be hard wired	Internet for small quantity
PL5	4 Pole, Audio Output, JST XH2.54mm	Optional – can be hard wired	Internet for small quantity
PL6	2 Pole, LED Power connector, JST XH2.54mm	Optional – can be hard wired	Internet for small quantity
SK1	RCA Input Jack - White	Left Channel Input	Cricklewood PCAW
SK2	RCA Input Jack - Red	Right Channel Input	Cricklewood PCAR
SK3A	6.35mm Jack socket, 3 Pole 2 channel	Stereo Headphone Socket alt. RS 143-8933	Cricklewood NMJ6HFD2
SK3B	3.5mm Jack socket, 3 Pole 2 channel	Stereo Headphone Socket 6mm Mounting.	eBay – Pro-audio5
SK4	3 Pole, Power connector, JST XH2.54mm	Optional – can be hard wired	Internet for small quantity
SK5	4 Pole, Audio Output, JST XH2.54mm	Optional – can be hard wired	Internet for small quantity
SK6	2 Pole, LED Power connector, JST XH2.54mm	Optional – can be hard wired	Internet for small quantity
R1	100k Metal Film 1%, 0.25W		Cricklewood M100K
R2	120k Metal Film 1%, 0.25W		Cricklewood M120K
R3	470k Metal Film 1%, 0.25W		Cricklewood M470K
R4	100k Metal Film 1%, 0.25W		Cricklewood M100K
R5	120k Metal Film 1%, 0.25W		Cricklewood M120K
R6	470k Metal Film 1%, 0.25W		Cricklewood M470K
R7	2k7 Metal Film 1%, 0.25W		Cricklewood M2K7
C1	4.7uF	ANSAR, alternative an Audyn Q4 from Banzai	Cricklewood CMON4V7
C2	4.7uF	ANSAR, alternative an Audyn Q4 from Banzai	Cricklewood CMON4V7
C3	100nF Ceramic, 50V		Cricklewood CZF100N
C4	100nF Ceramic, 50V		Cricklewood CZF100N
IC1	NJM4556D Dual Op-Amp, 70mA drive		Cricklewood NJM4556D
RV1	Dual 100k Log, ALPS?	eBay purchase with interface PCB	eBay – jgvknymwp
Z1	12V Zener diode, 400mW, BZY8812V		Cricklewood Z12V
SW1	Double Pole Single Throw Toggle switch	6mm Mounting Hole	Cricklewood TU22N1
BAT1	PP3 Alkaline Battery		Cricklewood ALKGP3
BAT2	PP3 Alkaline Battery		Cricklewood ALKGP3

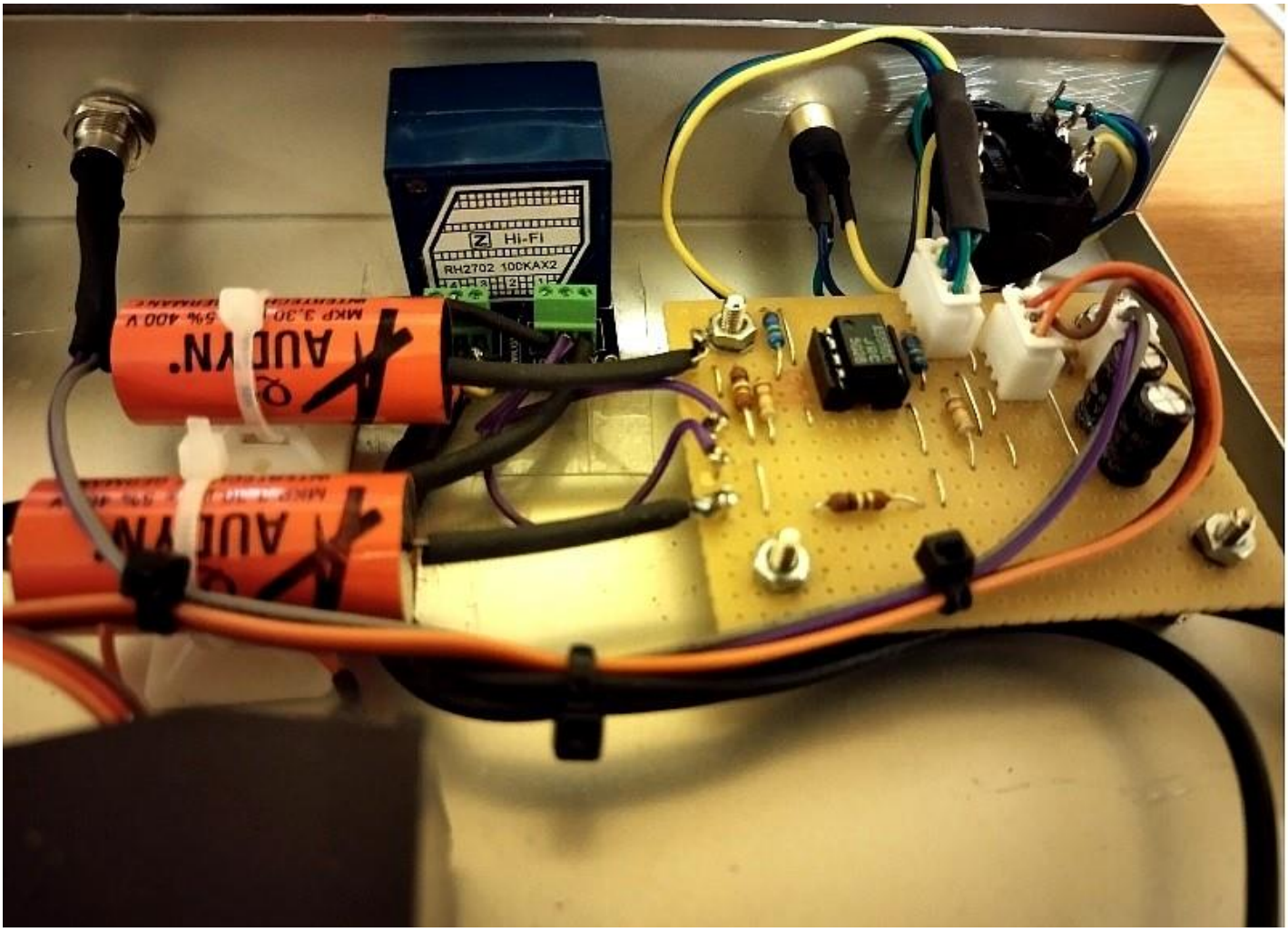
Views of the prototype

Front Panel before labels were fitted.

Interior of prototype



Another interior view

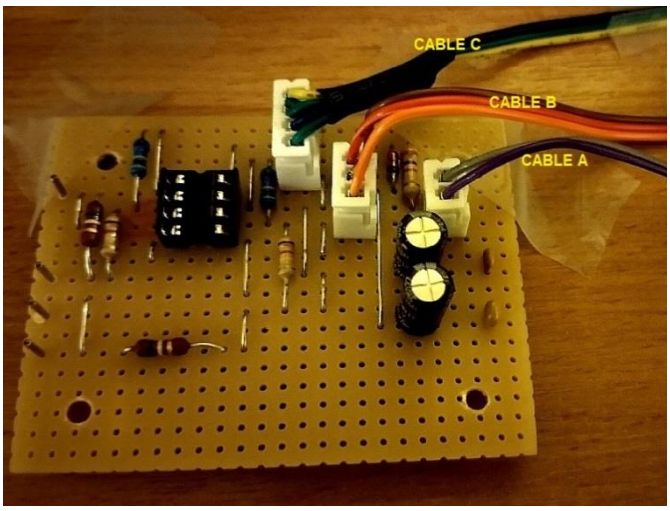


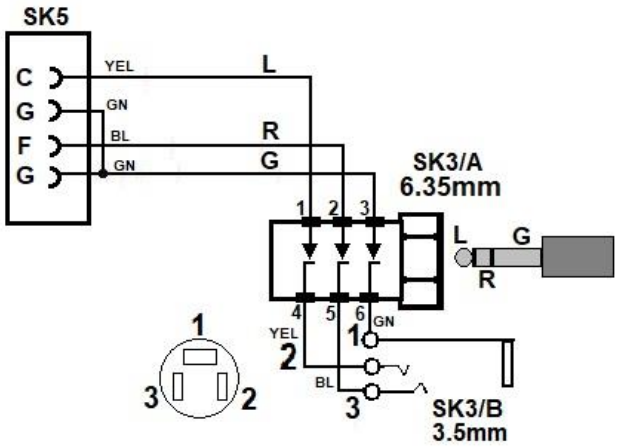
NOTE: Wire colours for SK3b are incorrectly shown and it was necessary afterwards to reverse the Blue and Yellow wires to get the Left and Right channels correct. The ¼" Jack was OK and worth mentioning that the channels should be checked to ensure Left Input goes to Left Headphone on both outputs and the Right channel input likewise goes to Right Headphone on both outputs.

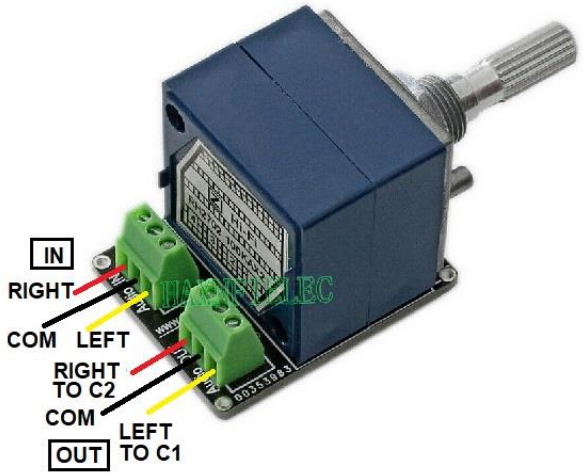
Wiring Schedule

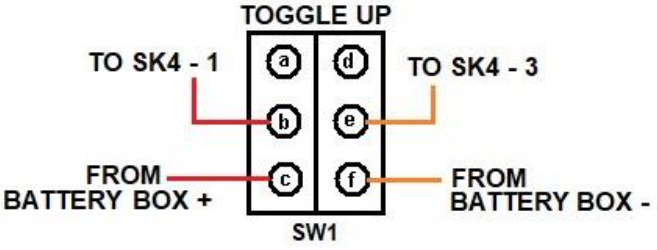
Colours are optional and those given are what the author used.

Line No.	FROM	TO	COLOUR	REMARKS
1	SK1 – inner	RV1a	Yellow	To RV1a input, See sketch below
2	SK1 – screen	RV1a & b	Black heat shrink	With Wire number 4
3	SK2 – inner	RV1b	Red	To RV1b input, See sketch below
4	SK2 – screen	RV1a & b	Black heat shrink	With Wire number 2
5	PCB Pin B	RV1 output Gnd	Black	With Wire 6
6	PCB Pin E	RV1 output Gnd	Black	With Wire 5
7	PCB Pin A	One end of C1	Black heat shrink	See sketch below
8	Other end of C1	RV1a OUTPUT	Black heat shrink	See sketch below
9	PCB Pin D	One end of C2	Black heat shrink	See sketch below
10	Other end of C2	RV1b OUTPUT	Black heat shrink	See sketch below
11	PCB PL6 – 4	LED 1 Anode	Grey	Pre-made cable A
12	PCB PL6 – 5	LED 1 Cathode	Violet	Pre-made cable A
13	PCB PL4 –1	SW1-b	Red +9V	Pre-made cable B, See sketch below
14	PCB PL4 – 2	Battery Box Com	Brown – connects BAT 1 (-) to BAT 2 (+)	Pre-made cable B
15	PCB PL4 – 3	SW1-e	Orange -9V	Pre-made cable B, See sketch below
16	SW1 – c	BAT 1 +ve	Red +9V	See sketch below
17	SW1 – f	BAT 2 -ve	Orange -9V	See sketch below
18	SK5 – C	SK3A – 1 (TIP)	Yellow	Pre-made cable C
19	SK3A – 4 (TIP)	SK3B – 2 (TIP)	Yellow Link cable from SK3A Tip switch	Left channel
20	SK5 – F	SK3A – 2 (RING)	Blue	Pre-made cable C
21	SK3A – 5 (RING)	SK3B – 3 (RING)	Blue Link cable from SK3A Ring switch	Right channel
22	SK5 – G	SK3A – 3 (GND)	Green	Pre-made cable C (Both G contacts linked)
23	SK3A – 6 (GND)	SK3B – 1 (GND)	Green Link cable from SK3A GND switch	Common ground

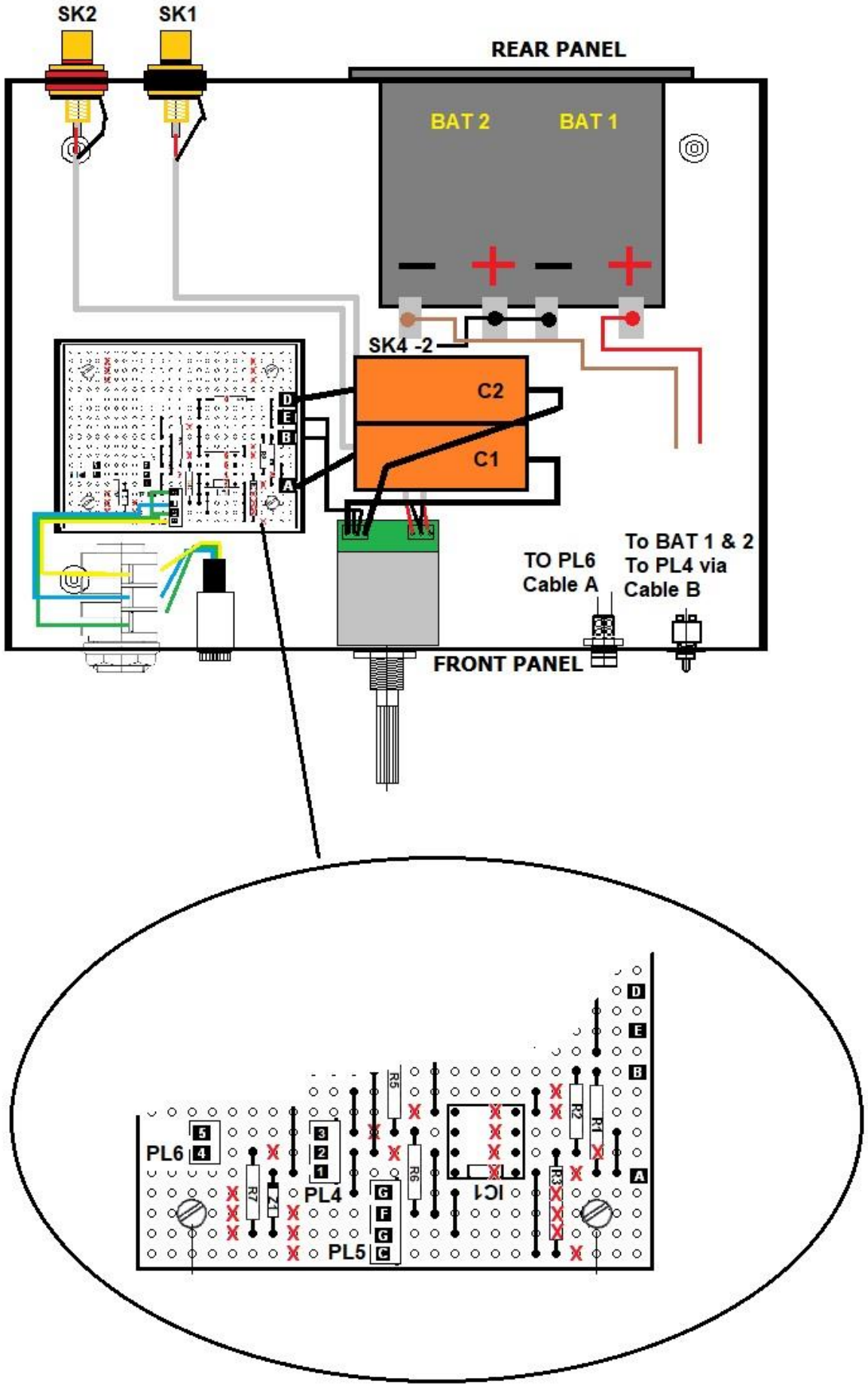






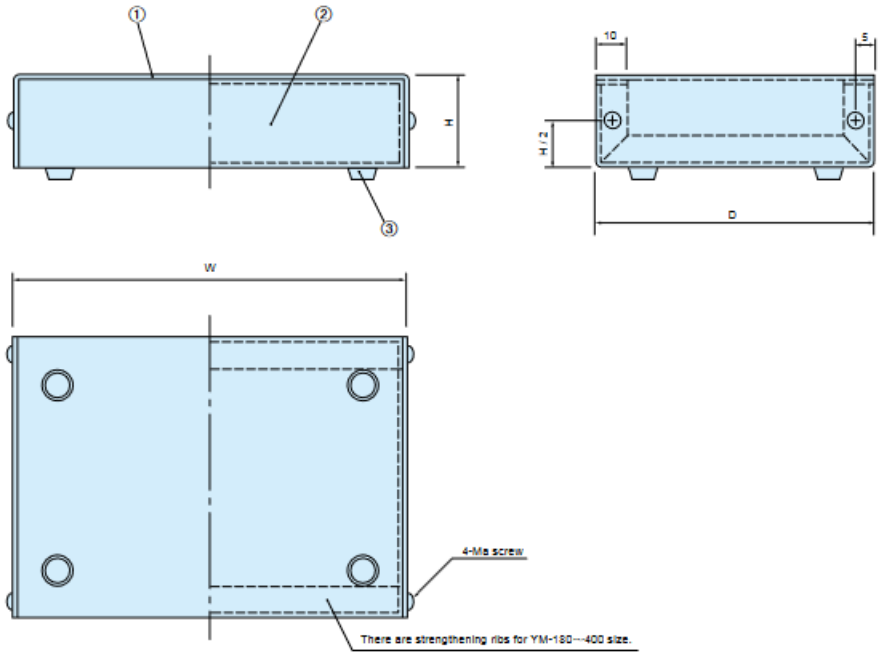


Wiring


SK2
SK1
REAR PANEL
BAT 2
BAT 1
SK4 -2
C2
C1
D
E
B
A
TO PL6
Cable A
To BAT 1 & 2
To PL4 via
Cable B
FRONT PANEL
PL6
PL4
PL5
IC1
R5
R6
R7
R2
R1
R3
ZD1
G
F
G
C

Takachi YM-200

YM180 – 400 Dimension



Part no. / dimensions

Part no.	W	H	D	a	Weight (g)
YM−180	180	40	130	M3	230
YM−200	200	40	150	M3	280
YM−250	250	50	170	M3	395
YM−300	300	50	200	M3	525
YM−350	350	55	230	M3	680
YM−400	400	55	250	M3	815

Commissioning Instructions.

With IC1 removed, insert two PP3 Alkaline batteries into the rear panel battery drawers.
Set front panel switch to ON and verify that the Blue LED is illuminated.

Typical Voltages (No Integrated circuits) are:-

IC1 Pin 1	IC1 Pin 2	IC1 Pin 3	IC1 Pin 4	IC1 Pin 5	IC1 Pin 6	IC1 Pin 7	IC1 Pin 8
Unstable O/C	**Unstable O/C**	**Unstable O/C**	**-9V**	**Unstable O/C**	**Unstable O/C**	**Unstable O/C**	**+9V**

Hopefully this test may find any critical accidental short circuits on the strip board.

Switch OFF, Insert IC1 and switch ON.

Typical Voltages (Integrated circuit fitted) are:-

IC1 Pin 1	IC1 Pin 2	IC1 Pin 3	IC1 Pin 4	IC1 Pin 5	IC1 Pin 6	IC1 Pin 7	IC1 Pin 8
+3.1mV	**+9.7mV**	**+8mV**	**-9V**	**+8.5mV**	**+8.9mV**	**+5.8mV**	**+9V**

Observations made from 1st manufactured unit.

A 1 kHz AC signal source was connected into the rear panel socket SK1 (Left channel) and the signal was verified with an oscilloscope connected to the Tip contact of SK3a (1) and then to SK3b (2).
The signal source was adjusted as required for no distortion i.e. no clipping on positive or negative peaks of the AC waveform.

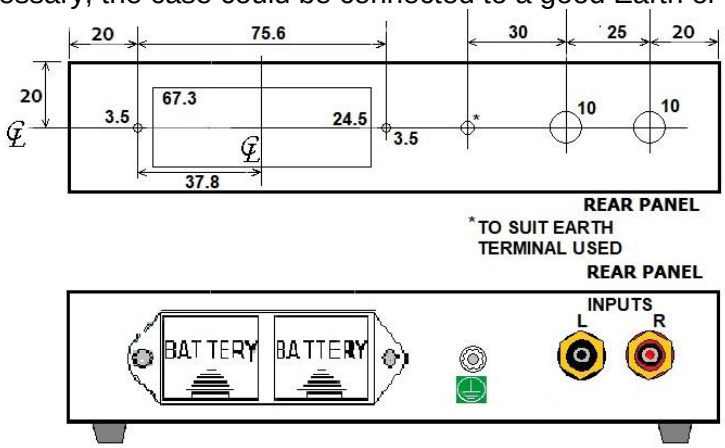
The no clipping input voltage was measured on a RMS Voltmeter to be 1.1V.
The output voltage was measured on the RMS Voltmeter to be 5.4V.
Gain of amplifier was measured as 13.7dB and was essentially flat with -3dB fall off occurring at 280 kHz.

The results for the Right channel using rear panel socket SK2 were virtually identical, the oscilloscope and RMS Voltmeter being connected to first the Ring contact of SK3a (2) then to SK3b (3).

The performance on a test with a RIAA amplifier was outstanding, some might say the audio was a little on the bright side but perhaps this is due to the incredible short signal path?
The frequency response was retested but there was no difference in response.
This was essentially flat from 10Hz up to 200 kHz.

Case Ground

Whilst testing with a JVC Quartz locked turntable and a 3 tube RIAA amplifier, hum was present in very copious amounts, even with shorting plugs in place of the turntable inputs. Noise dramatically cleared to total silence if the case of the clone was connected to a good grounding point, this was totally unexpected as the clone had its own DC power supply. So a Ground terminal was added to the rear panel so that, where necessary, the case could be connected to a good Earth or Ground.



The NJM4556D Op-Amp

Electrical Characteristics

JRC

DUAL HIGH CURRENT OPERATIONAL AMPLIFIER

NJM4556

The NJM4556 integrated circuit is a high-gain, high output current dual operational amplifier capable of driving ± 70mA into 150Ω loads (±10.5V output voltage). The NJM4556 combines many of the features of the popular NJM4558 as well as having the capability of driving 150Ω loads. In addition, the wide band-width, low noise, high slew rate and low distortion of the NJM4556 make it ideal for many audio, telecommunications and instrumentation applications.

■ Absolute Maximum Ratings (Ta=25°C)

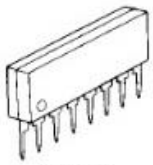
Supply Voltage	V^+/V^-	±18V
Differential Input Voltage	V_{ID}	±30V
Input Voltage(note)	V_I	±15V
Power Dissipation	P_D (D-Type)	700mW
	(M-Type)	300mW
	(L-Type)	800mW
Operating Temperature Range	T_{opr}	−20~+75°C
Storage Temperature Range	T_{stg}	−40~+125°C

(note) For supply voltage less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

■ Package Outline

NJM4556D

NJM4556M-B



NJM4556L

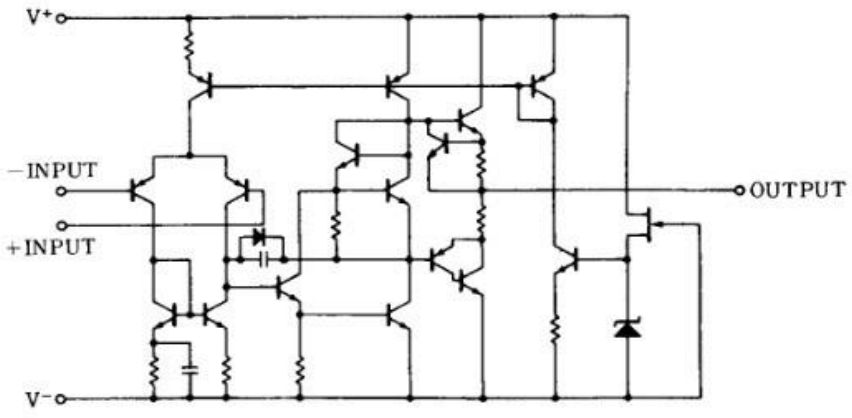
■ Electrical Characteristics (NJM4556D/NJM4556L)(Ta=25°C, V^+/V^-=±15V)

Parameter	Symbol	Test Condition	Min.	Typ.	Max.	Unit
Input Offset Voltage	V_{IO}	R_S≤10kΩ	—	0.5	6	mV
Input Offset Current	I_{IO}		—	±5	±60	nA
Input Bias Current	I_B		—	180	500	nA
Large Signal Voltage Gain	R_{IN}		0.3	5	—	MΩ
Large Signal Voltage Gain	A_V	R_L≥2kΩ, V_O=±10V	86	100	—	dB
Maximum Output Voltage Swing 1	V_{OM1}	R_L≥2kΩ	±12	±13.5	—	V
Maximum Output Voltage Swing 2	V_{OM2}	R_L≥150Ω	±10.5	±11	—	V
Input Common Mode Voltage Range	V_{ICM}		±12	±14	—	V
Common Mode Rejection Ratio	CMR	R_S≤10kΩ	70	90	—	dB
Supply Voltage Rejection Ratio	SVR	R_S≤10kΩ	76.5	90	—	dB
Supply Current	I_{CC}		—	9	12	mA
Slew Rate	SR		—	3	—	V/μS
Unity Gain Bandwidth	GB		—	8	—	MHz

Circuit and base diagrams

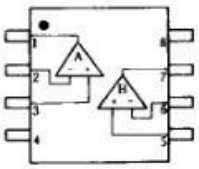
NJM4556

■ **Equivalent Circuit** (½ Shown)



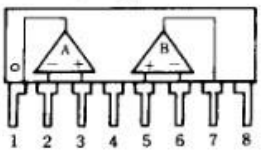
■ **Connection Diagram**

D,M-Type
(Top View)



PIN FUNCTION
1. A OUTPUT
2. A−INPUT
3. A+INPUT
4. V⁻
5. B+INPUT
6. B−INPUT
7. B OUTPUT
8. V⁺

(L-Type)



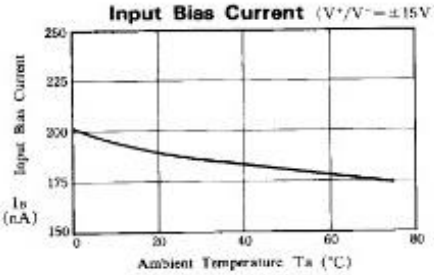
■ **Electrical Characteristics** (NJM4556M-B) ($V^+/V^-=\pm15V$, Ta=25°C)

Parameter	Symbol	Test Condition	Min.	Typ.	Max.	Unit
Input Offset Voltage	V_{IO}	$R_S \leq 10k\Omega$	—	0.5	0.5	mV
Input Offset Current	I_{IO}		—	30	60	nA
Input Bias Current	I_B		—	250	500	nA
Large Signal Voltage Gain	A_V	$R_L \geq 2k\Omega$, $V_O=\pm10V$	86	100	—	dB
Maximum Output Voltage Swing 1	V_{OM1}	$V_{IN}^+=4V$, $V_{IN}^-=3V$, $V^+=9V$ $I_{SOURCE}=40mA$	7.5			V
Maximum Output Voltage Swing 2	V_{OM2}	$V_{IN}^+=3V$, $V_{IN}^-=4V$, $V^+=9V$ $I_{SINK}=40mA$	—	—	2.1	V
Input Common Mode Voltage Range 1	V_{ICM1}	$V^+=9V$, V_{IL}	—	—	1.5	V
Input Common Mode Voltage Range 2	V_{ICM2}	$V^+=9V$, V_{IH}	8	—	—	V
Common Mode Rejection Ratio	CMR	$R_S \leq 10k\Omega$	70	90	—	dB
Supply Voltage Rejection Ratio	SVR	$R_S \leq 10k\Omega$	76.5	90	—	dB
Power Dissipation	P_D	$V^+=9V$	—	80	135	mW

Graphs

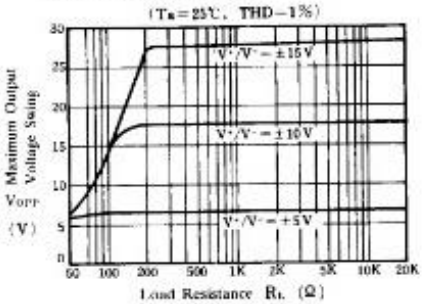
■ **Typical Characteristics**

Input Bias Current ($V^+/V^-=\pm15V$)



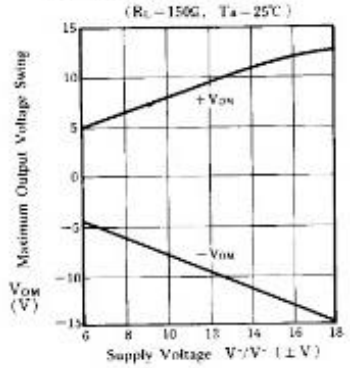
Maximum Output Voltage Swing vs. Load Resistance

($T_a=25°C$, THD=1%)



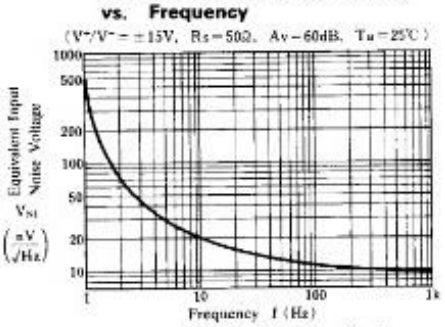
Maximum Output Voltage Swing vs. Supply Voltage

($R_L=150Ω$, $T_a=25°C$)



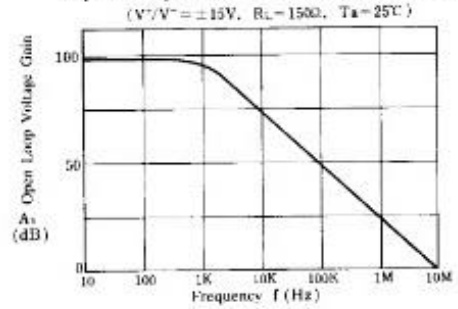
Equivalent Input Noise Voltage vs. Frequency

($V^+/V^-=\pm15V$, $R_S=50Ω$, $A_V=60dB$, $T_a=25°C$)



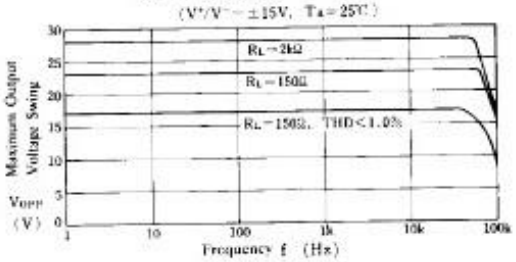
Open Loop Voltage Gain vs. Frequency

($V^+/V^-=\pm15V$, $R_L=150Ω$, $T_a=25°C$)



Maximum Output Voltage Swing vs. Frequency

($V^+/V^-=\pm15V$, $T_a=25°C$)



Total Harmonic Distortion vs. Output Voltage

($V^+/V^-=+15V$, $A_V=30dB$, $R_L=200Ω$, $T_a=25°C$)