# ACF-2

## Aikido Cathode Follower

## All-in-One
## 9-Pin

USER GUIDE



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# DANGER!

This PCB holds a high-voltage power supply; thus, a real—and possibly—lethal shock hazard exists.

Ideally, a variac should be used to slowly power up the regulator, as it is better to have a mis-oriented electrolytic capacitor or a mis-located resistor blow at low voltages, rather than at high voltages. Remember that the danger increases by the square of the voltage; for example, 200 volts is four times more dangerous than 100 volts and 400 volts is sixteen times more dangerous.

Once the power supply is powered up, be cautious at all times. In fact, even when the power supply is disconnected or shut down, assume that power-supply capacitors will have retained their charge and, thus, can still shock. If you are not an experienced electrical practitioner, before attaching the transformer windings to the board, have someone who is well-experienced in electronics review your work.

There are too few tube-loving solder slingers left; we cannot afford to lose any more.

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## ☛ Warning! ☚

This PCB contains a high-voltage power supply; thus, a real shock hazard exists. Once the power supply is attached, be cautious at all times. If you are not an experienced electrical practitioner, before applying the B-plus voltage have someone who is experienced review your work. There are too few tube-loving solder slingers left; we cannot afford to lose any more.

## ACF-2 PCB Overview

Thank you for your purchase of the Aikido ACF-2 9-pin stereo PCB. This FR-4 PCB is extra thick, 0.094 inches; thus, inserting and pulling tubes from their sockets won't bend or break this board; it double-sided, with plated-through 2oz copper traces on both sides; and the PCB is expensively and lovingly made in the USA. Each PCB holds two Aikido ACF-2 unity-gain buffers; thus, one board is all that is needed for stereo unbalanced use or one board for one channel of balanced buffering. The boards are four inches by six inches, with five mounting holes, which also helps to prevent excessive PCB bending while inserting and pulling tubes from their sockets.

## PCB Features

**Redundant Solder Pads** This board holds two sets of differently-spaced solder pads for each critical resistor, so that radial and axial resistors can easily be used (bulk-foil resistors and carbon-film resistors, for example).

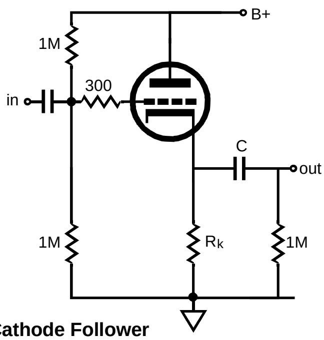
**B+ and Heater Power Supplies** On the ACF-2 PCB, two power supplies reside, a high-voltage bipolar and a low-voltage power supply for the heaters. The high-voltage power supply uses one RC filter per channel to smooth away ripple, while the low-voltage power supply uses a voltage regulator to provide a stable and noise-free voltage output. (The power supplies require an external power transformer(s) with two secondary windings; the high voltage secondary must be center-tapped.)

## No-Gain—No-Pain

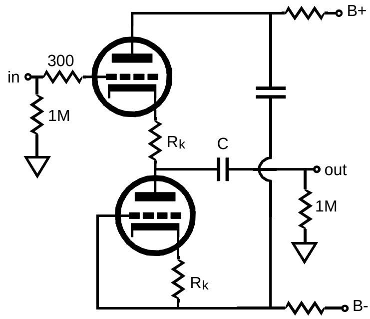
Finding a tube-based buffer line stage that provides no voltage gain is, surprisingly enough, difficult. As far as I know, no commercially-offered, unity-gain, tube-based line-stage buffer exists. This is an odd situation, as passive line-stages are popular, proving that extra voltage gain isn't always necessary. (Many signal sources, such as CD players or DACs deliver enough output signal to drive most amplifier to full output, so no additional voltage gain is required.) The purest of the pure, the passive line-stage does not require plugging into the wall and it adds no extra active devices into signal path.

Yet passive line stages often prove sonically inadequate, incapable of driving high-capacitance cables or low-input impedances. Moreover, an active line-stage amplifier often imparts the missing heft and solidity that is missing in many passive setups, which often sound thin and ghostly, even when the load is wimpy—albeit at the cost of greatly increased complexity and expensive. The ACF-2, in contrast, is a good compromise; it is both simple and effective. The ACF-2 offers a high input impedance, a low output impedance, low distortion, and a great PSRR figure. In addition, the ACF-2 does not invert the phase.

# Introduction to the Aikido ACF-2




**Cathode Follower**

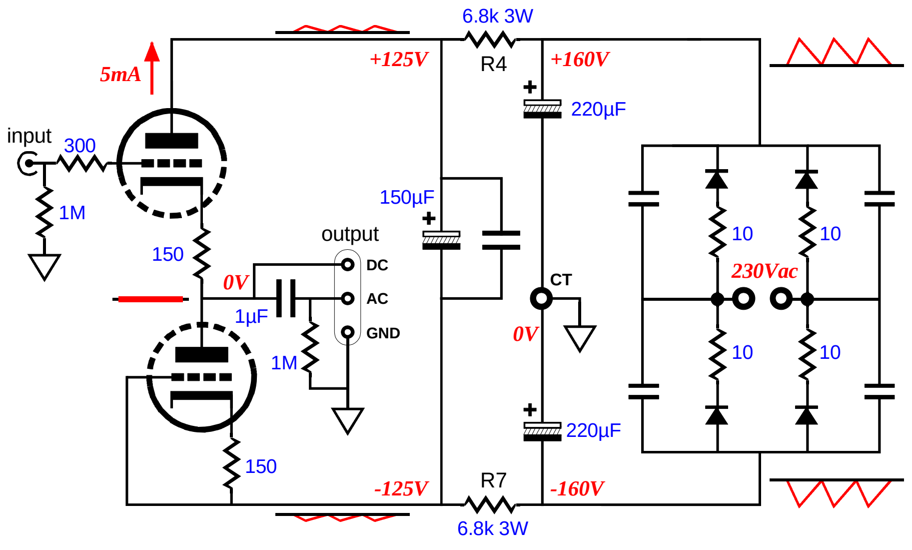



**Aikido ACF-2**

So what is required to make a good tube-based unity-gain buffer? For most tube fanciers, the immediate answer is to use a cathode follower. This response makes a lot of sense, as the cathode follower offers a gain close to unity, a low output impedance, and low distortion figure. In addition, the cathode follower is amazingly simple. The cathode follower, however, isn't perfect. Although its PSRR figure is quite good for a tube circuit, being roughly equal to 1/mu, it is quite poor by solid-state standards. Fortunately, squeezing more performance from the cathode follower requires only a bit more added complexity.

The ACF-2 uses a bipolar power supply and two triodes per channel to greatly improve its PSRR figure (and, possibly, to eliminate the need for an output coupling capacitor). The top triode defines a cathode follower with a DC input and an active cathode load, which is made up from the bottom triode and its cathode resistor. These two triodes and their matching cathode resistors balance each other perfectly, nulling the power-supply noise from the ACF's output. Imagine two identical resistors wired in series and spanning a bipolar power supply two voltage rails. Because both resistors are equal in value, the voltage division is one half. Thus if the two rail voltages differ only in polarity, the voltage at the resistors' common connection will be 0 volts. One half of +100V and -100V is 0V. The math holds up to the presence of noise on the bipolar power supply rails, which means that as long as the anti-phase relationship and amplitude of positive and negative power supply rail noise match, the output noise from these rails will equal zero at that same connection.

In addition, the ACF-2 produces a tad bit less distortion than comparable cathode follower by using the triode's own nonlinearity against itself. The triode is not as linear as a resistor so, ideally, it should not see a linear load, but a corresponding, complementary, balancing non-linear load. An analogy is found in someone needing eyeglasses; if the eyes were perfect, then perfectly flat (perfectly linear) lenses would be needed, whereas imperfect eyes need counterbalancing lenses (non-linear lenses) to see clearly. Now, loading a triode with the same triode—under the same cathode-to-plate voltage and idle current and with the same cathode resistor—works well to flatten the transfer curve out of that triode. Since the cathode follower already enjoys 100% degeneration at its cathode, the slight reduction in distortion by using the triode-based load is not as marked as in is in a grounded-cathode amplifier, but it is a worthwhile modification.




## Bipolar Power Supply

A high-voltage bipolar power supply resides on the ACF-2 PCB. It contains a full-wave bridge center-tap rectifier circuit and two reservoir capacitors, which are then followed by two RC-smoothing filters, one for each channel. The high voltage power transformer is external to the PCB and can be mounted in, or outside, the chassis that houses the PCB.

The optimal cathode-to-plate voltage depends on the tubes used. For example, 6GM8s (ECC86) can be used with a low +/-12Vdc power supply, while 6DJ8s work better with a +/-50Vdc to +/-120Vdc B+ voltage; 6CG7s and 12AU7s and ECC99s, +/-100Vdc to +/-150Vdc. The sky is not the limit here, as the maximum heater-to-cathode voltage set an upward limit of about +/-150Vdc. In addition, the 200V power-supply capacitors C19 & C18 are only rated for 200Vdc, which means that about +/-180V should be a self-imposed voltage limit. Resistors

R4 and R7 are the "R"s in the bipolar RC power supply filters. Increasing their value will reduce the cathode-to-plate voltage across the triodes. Resistor heat equals $I^2 \times R$ (and $V^2/R$); for example, 20mA and 5k will dissipate 2W. See the inside back cover for more voltage and current limit information.

There are several goals that work against each other: we want the largest voltage-dropping resistor value possible, as it reduces the ripple appearing at the tubes' power supply connection; we want the lowest raw B-plus voltage possible, as it will allow a larger-valued reservoir capacitor and limit the heater-to-cathode voltage; and we want the highest plate voltage possible for the triodes, as it makes for better sound. We cannot have it all. For example, the typical 250V capacitor is much more volumetrically efficient than a 400V capacitor. Thus, running a lower B+ voltage allows us to increase greatly the capacitance in the power supply. Running lighter current allows us to maximize resistors R4 & R7 values.

## Tube Selection

The only stipulations are that the two triodes within the envelope be the same and that the tube conforms to the 9A or 9AJ base pin-out. The higher the mu, the closer to unity gain. The higher the transconductance, the lower the output impedance. For most, the 6AQ8, 6CG7, 6DJ8, 12AU7, 12BH7, or ECC99 will the first choices. Other possible choices are 6H30, which would deliver a low output impedance that could drive capacitance-laden cables; and the 5963 & 5965, which were design for long life in computers. In other words, the list of possible tubes is a long one: 6AQ8, 6BC8, 6BK7, 6BQ7, 6BS8, 6DJ8, 6FQ7, 6GC7, 6H30, 6KN8, 6N1P, 12AT7, 12AU7, 12AV7, 12AX7, 12BH7, 12DJ8, 12FQ7, 5751, 5963, 5965, 6072, 6922, E188CC, ECC88, ECC99…

Sadly, the 12B4 and 5687 cannot be used with this PCB.

## Internal Shields

If the triode's pin 9 attaches to an internal shield, as it does with the 6AQ8 and 6DJ8, then capacitors C2 can be replaced with a jumper, which will ground the shield. However, using the capacitors rather than jumpers will also ground the shield (in AC terms) and allow swapping in triodes whose pin-9 attaches to the center tap of its heater, such as the 12AU7.

## Cathode Resistor Values

The cathode resistor and plate voltage set the idle current for the triode: the larger the value of the resistor, less current; the higher the plate voltage, more current. In general, high-mu triodes require high-value cathode resistors (560 - 1K) and low-mu triodes require low-valued cathode resistors (100 - 470). The formula for setting the Iq is an easy one:

**Iq = B+/(rp + [mu + 1]Rk)**

So, for example, a 6CG7 in an ACF-2 with rail voltages of +100Vdc/-100Vdc and 240 cathode resistors will draw 100/(8k + [20 + 1]240) amperes of current, or 7.7mA. I recommend 680 to 1.1k for the 12AX7, 5751, 6072 tubes and 100 to 330 for the 6DJ8 and 6N1P tubes. Other tubes, such as the 6CG7, 12AT7, 12AU7, 12BH7 work well with 300-ohm cathode resistors. Because the cathode resistors see so little voltage differential, 1/2W resistors can readily be used. Be sure to see the tube chart on the last page for many illustrations.

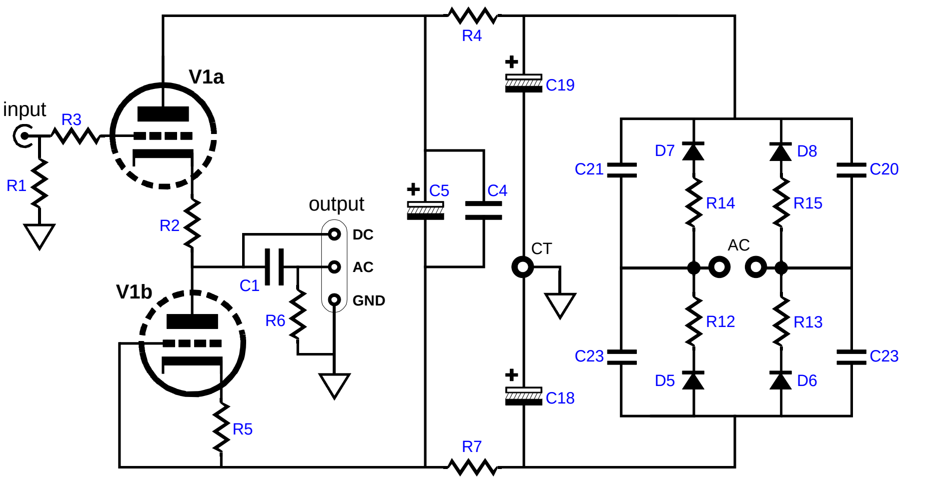
## Coupling-Capacitor Values

The bigger in value the coupling capacitor (C1), the lower the -3dB high-pass corner frequency will be. The formula is as follows:

**Frequency = 159155/C/R**

where C is in µF. For example, with a 1µF coupling capacitor and a power amplifier with an input impedance of 47k, the corner frequency would be 3.5Hz. The higher the load impedance, the lower the corner frequency. The coupling capacitor voltage rating must at least equal the B+ voltage, for safety's sake. Although pads weren't provided for bypass capacitors for the coupling capacitors, a small bypass capacitor can be solder on the bottom of the PCB, using two of the redundant solder pads.

## 9-Pin Aikido CF-2 Schematic




## Typical Part Values

() Parentheses denote recommended values

| | 6CG7 | 6DJ8 | 12AU7 | 6GM8<br>Low-Voltage Operation | 6H30<br>High Current Operation |
|---|---|---|---|---|---|
| **Secondary Vac =** | 240V CT | 240V CT | 240V CT | 24V CT | 120V CT |
| **Heater Voltage =** | 6.3V @ 1.2A<br>12.6V @ 0.6A | 6.3V @ 0.7A<br>12.6V @ 0.35A | 12.6V @ 0.3mA<br>12.6V @ 0.3A | 6.3V @ 0.7A<br>12.6 @ 0.35A | 6.3 @1.65A<br>12.6V @ 0.825A |
| **R1, 6 =** | 1M | 1M | 1M | 1M | 1M |
| **R3 =** | 100 - 1k (300)* | 100 - 1k (300)* | 100 - 1k (300)* | 100 - 1k (300)* | 100 - 1k (300)* |
| **R2, 5 =** | 200 - 1k (470)* | 100 - 1k (200)* | 200 - 1k (300)* | 300 - 680 (180)* | 100 - 470 (150)* |
| **R4, 7 =** | 3.9k | 3.9k | 3k | 10k | 1.6k |
| **V1, V2 = (Subs)** | 6CG7, 6FQ7, 8CG8<br>12FQ7 | 6922, 7308, E88CC | 6AU7, 5814, 5963,<br>6189, ECC82 | ECC86, 6N27P | None |

*High-quality resistors essential in this position. All resistors 1/2W or higher

| | 6N1P | 12BH7 | 12AT7 | ECC99 | 5965 |
|---|---|---|---|---|---|
| **Secondary Vac =** | 240V CT | 240V CT | 240V CT | 240V CT | 240V CT |
| **Heater Voltage =** | 6.3V @ 1.2A<br>12.6V @ 0.6A | 12.6V @ 0.6A | 12.6V @ 0.3mA | 12.6 @ 1.5A | 12.6 @ 0.225A |
| **R1, 6 =** | 1M | 1M | 1M | 1M | 1M |
| **R3 =** | 100 - 1k (300)* | 100 - 1k (300)* | 100 - 1k (300)* | 100 - 1k (300)* | 100 - 1k (300)* |
| **R2, 5 =** | 200 - 1k (300)* | 100 - 1k (390)* | 200 - 1k (340)* | 300 - 680 (470)* | 100 - 470 (240)* |
| **R4, 5 =** | 3.9k | 2k | 10k | 3k | 3.9k |
| **V1, V2 = (Subs)** | 6BQ7, 6BS8, 6BZ7 | 12BH7A-EH | 6201, CV4024, ECC81 | 6H6P<br>(place 6.3V heaters in series) | 12AV7 |

*High-quality resistors essential in this position. All resistors 1/2W or higher

| | | | | | |
|---|---|---|---|---|---|
| **C1 =** | 0.1 - 4µF* Film or PIO | Same | Same | Same | Same |
| **C2 =** | 0.01 - 0.1µF 100V | " | " | " | " |
| **C3 =** | 1KµF/16V (optional) | " | " | " | " |
| **C4 =** | 0.1 - 10µF 400V | " | " | " | " |
| **C5 =** | 150µF 400V | " | " | " | " |
| **C20 - C23 =** | 0.01µF 1kV Ceramic | " | " | " | " |
| **C24 - C27 =** | 0.1µF 50V Ceramic | " | " | " | " |
| **C18, C19 =** | 47 - 470µF 450V | " | " | " | " |

*Voltage rating must equal or exceed B+ voltage

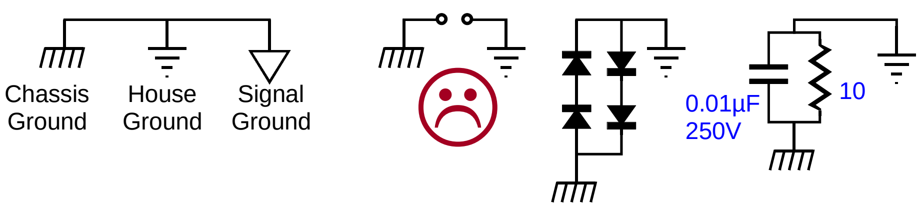
## Grounding

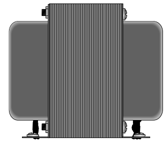
The ACF-2 PCB holds a star ground at its center. Ideally, this will be the only central ground in a line-stage buffer. A ground-loop is created when a device finds more than one connections to ground. Ground loops, unfortunately, are extremely easy to introduce. For example, if the input and output RCA jacks are grounded at the chassis, then the twisted pair of wires that connect the PCB to the jacks will each define a ground loop, as the chassis will attach to the PCB's central ground through at least four wires. The solution is either to isolate the jacks or use only a single hot wire from each jack to PCB (the wire can be shielded, as long as the shield only attaches at one end). Thus, the best plan is to plan. Before assembling the line-stage amplifier, stop and decide how the grounding is going to be laid out, then solder.

Three different schools of thought hold for grounding a piece of audio gear. The Old-School approach is to treat the chassis as the ground; period. Every ground connection is made at the closest screw and nut. This method is the easiest to follow and it produces the worst sonic results. Steel and aluminum are poor conductors.

The Spur-Star ground method uses several ground "stars," which then terminate in a single star ground point, often a screw on the chassis. This system can work beautifully, if carefully executed. Unfortunately, often too much is included in each spur connection. For example, all the input and output RCA jacks share ground connection to a long run of bare wire, which more closely resembles a snake than a spur ground. In other words, the spurs should not be defined just physical proximity, but signal transference. Great care must be exercised not to double ground any spur point. For example, the volume control potentiometer can create a ground loop problem, if both of its ground tabs are soldered together at the potentiometer and twisted pairs, of hot and cold wires, arrive at and leave the potentiometer, as the two cold wires attaching to the PCB will define a ground loop. The Absolute-Star grounding scheme uses a lot of wire and is the most time consuming to lay out, but it does yield the best sonic rewards. Here each input signal source and each output lead gets its own ground wire that attaches, ultimately, at one star ground point; each RCA jack is isolated from the chassis. The ACF-2 PCB was designed to work with this approach, although it can be used with any approach.

**House Ground** The third prong on the wall outlet attaches to the house's ground at the service panel and usually the cold water pipe. The line-stage buffer can also attach to this ground connection, which is certainly the safest approach, as it provides a discharge path should the high voltage short to the chassis. Unfortunately, this setup often produces a hum problem. Some simply float the chassis (not safe!), others use several solid-state rectifiers in parallel to attach the chassis ground to the house ground (**NOT NEUTRAL**) via the third prong, and others still use a power 10-ohm resistor shunted by a small capacitor, say 0.001µF to 0.1µF/250V.





## Power Transformer(s)

The ACF-2 PCB requires a power transformer(s) to energize its two power supplies. When set up with a full-wave bridge rectifier topology, the heater power supply power transformer secondary must offer at least 1.8 times more current than the heaters will draw. For example, two 6CG7s will draw 0.6A @12.6v, so the heater power transformer must be able to sustain an AC 1.08A current draw. In addition, with sine waves, the AC voltage equals the peak voltage divided by the square root of 2, i.e. 1.414. Thus, a 10Vac sine wave peaks at 14.14V; a 6.3Vac, 8.9V. In other words, a sine wave that peaks at 14.14V will produce the same amount of heat in a resistance as a 10Vdc voltage source would produce in the same resistance; thus, we label the 14.14Vpk sine wave as being 10Vac. Thus, in order to get the 16Vdc a 12.6V heater voltage regulator requires an input voltage equal to sum of 16V and the rectifier loss (about 2V) divided by 1.414, which is roughly 12.6Vac.

The high voltage power transformer must also follow the same rules. Thus, to achieve 340V (+/-170Vdc) of raw DC voltage, before the two RC filters, the high-voltage transformer secondary must deliver (340V + 2V) / 1.414, or about 240Vac center-tapped. And if 50mA is required, the power transformer must be rated for 50mA x 1.8, or about 90mA. Such a transformer VA rating would equal 33VA. The high voltage secondary must be center-tapped (or consists of two secondaries that can be placed in series, thus creating a center-tap). Do not use an autoformer type step-up transformer, as the primary and secondary must be isolated from each other.

The transformer's secondary maximum voltage limit is about 280Vac CT (140V-0V-140V), as the RC filter capacitors C4 & C5 present a strict 400Vdc voltage limit. (Remember, when a tube is cold, it doesn't conduct, so the RC filter will not diminish the full bipolar power supply differential voltage.)

Two good choices are the Edcor XPWR054-120 and the Hammond 269AX (or 369AX). Both of these transformers hold a high voltage secondary and a low-voltage heater winding. On the other hand, two individual power transformer could be used, say a 240Vac CT transformer for the bipolar power supply and a 12.6Vac transformer for the heater section.

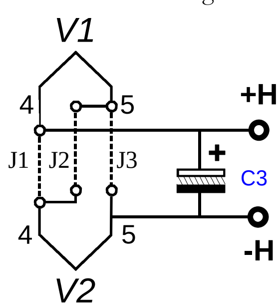
**Toroidal Transformers** Theoretically, the toroid is one of best choices of the easily available transformers. But, like so many good theories, practice proves difficult. First, the attributes: low radiated magnetic fields, better regulation, smaller, lighter, and cooler running. The obvious downside is higher cost. Where a conventional EI power transformer can be easily and quickly assembled by simple machines, toroids require much more labor and elaborate machines. The next disadvantage is surprising: toroids can be dreadfully noisy, not in terms of magnetic fields, but in terms of mechanical buzzing. Even the wire itself can buzz. Finding a low-mechanical-noise toroid can be quite difficult. Additionally, toroids often pass much more RFI than a comparable clunky EI power transformer would. Because the toroid's primary and secondary lie next to each other, there is more capacitive coupling between the windings.

## Heater Issues

The ACF-2 PCB holds the heater raw power supply and low-voltage regulator, the LD1085 low-dropout adjustable voltage regulator. The regulator can be set to an output voltage between 6V to 25V, but the assumption is that a 12Vdc output voltage will be used for the heaters, so that 6.3V heater tubes (like the 6FQ7 and 6DJ8) or 12.6V tubes (like the 12AU7 or 12AX7) can be used. Both voltage types must be used exclusively; for example a 6GC7 and a 12BH7 cannot be used at the same time. Thus, if tubes (V1 and V2) are 6CG7s and the heater regulator output voltage is 12Vdc, then use jumpers J2 solely, as it will place the two heater elements in series; if the tubes are 12V types, such as the 12AU7 and ECC99, then use jumpers J1 & J3, as this will place the heaters elements in parallel.

As can be seen, the power supply can accept either full-wave bridge rectifier circuit or a full-wave voltage doubler rectifier configuration. Configured as a voltage doubler, which is a good choice when the heater secondary voltage is only 6.3Vac, capacitors C28 & C29 must be placed in series by being rotated 90 degrees clockwise, so the positive leads point to the center-tap pad at the bottom of the PCB; the secondary attaches to single AC pad in between capacitors C28 and C29 and AC pad that feeds rectifier D9 and D11; and D10, D12, C25, C27 are left off the PCB. If used as a full-wave center-tap circuit, the two power supply filtering capacitors are placed in parallel by orienting their positive leads to where the heatsink sits; and the secondary attaches to the two encircled AC pads and the secondary center-tap attaches to the CT pad.

Since one triode stands atop another, the heater-to-cathode voltage experienced differs between triodes. The safest path is to reference the heater power supply to a voltage equal to one half the B- voltage; for example, -50V, when using a +/-100V power supply. This voltage ensures that both top and bottom triodes see the same magnitude of heater-to-cathode voltage. Resistors R8 & R9 establish this voltage relationship.



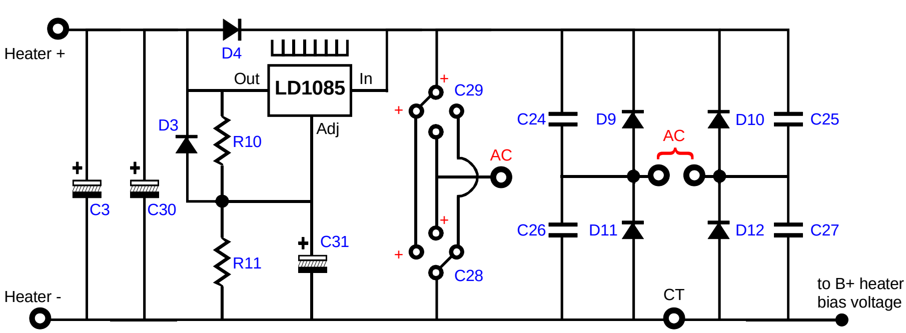

### Filament Jumper Wire Schedule

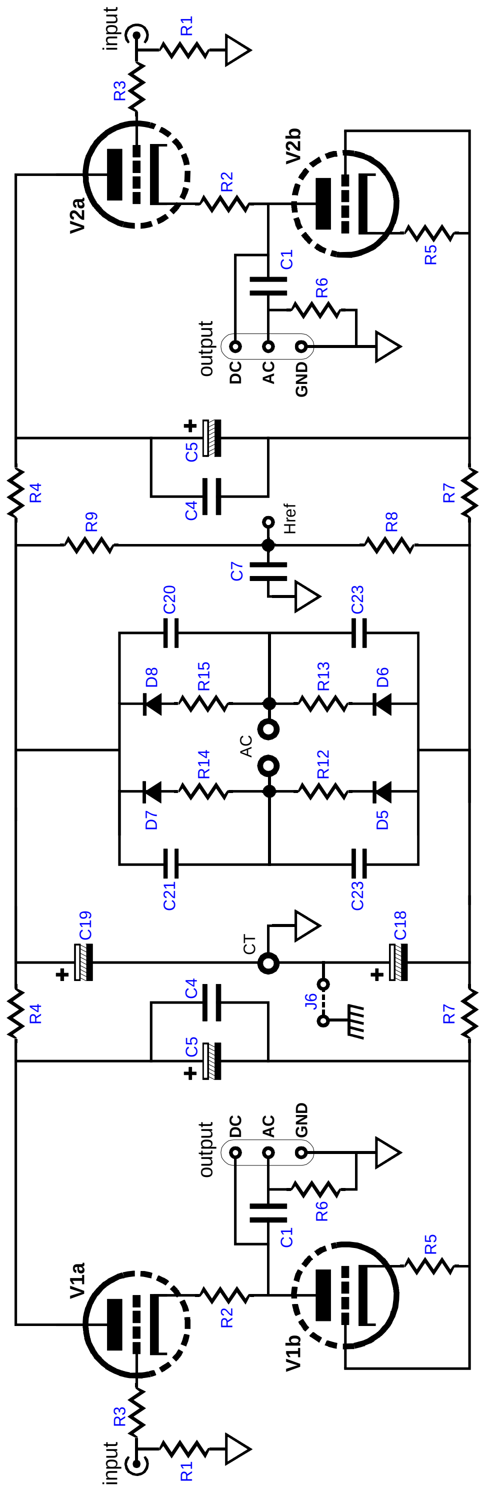
**With a 12.6V PS**

| | |
|---|---|
| Both tubes are 6.3V: | J2 only |
| If both are 12.6V: | J1 & J3 |

**With a 6.3V PS**

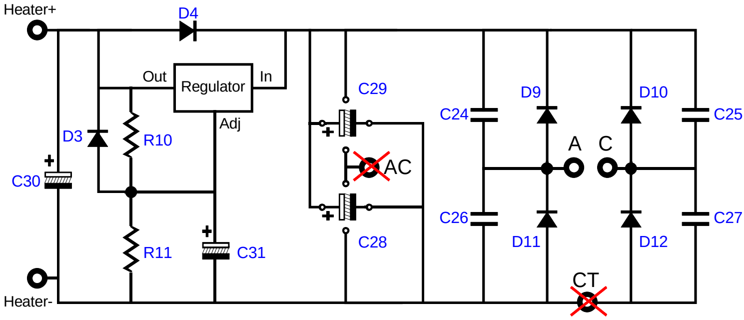
| | |
|---|---|
| All tubes = 6.3V: | J1 & J3 |
| If both are 12.6V: | Cannot be used with 6.3V PS |




input
R1
R3
V2a
R2
V2b
R5
C1
R6
output
DC
AC
GND
C5
C4
R4
R7
R9
R8
Href
C7
C20
C23
D8
R15
R13
D6
AC
R14
R12
D7
D5
C21
C23
C19
C18
CT
J6
R4
C4
R7
C5
output
DC
AC
GND
R6
C1
R5
V1a
R2
V1b
R3
input
R1

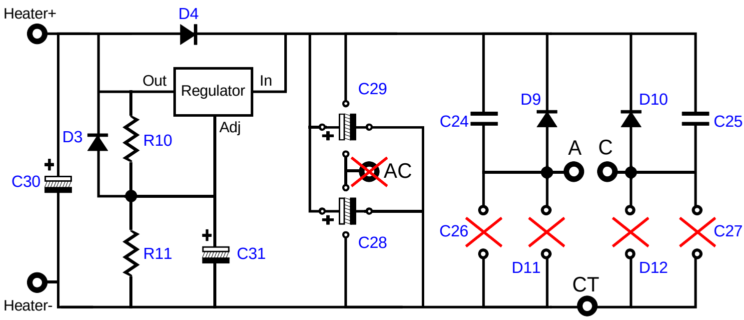
# Full-Wave Bridge

Capacitor C28 & C9 positive leads pointing to heatsink
Fullwave-Bridge Rectification. Raw DC voltage = 1.414Vac - 2V



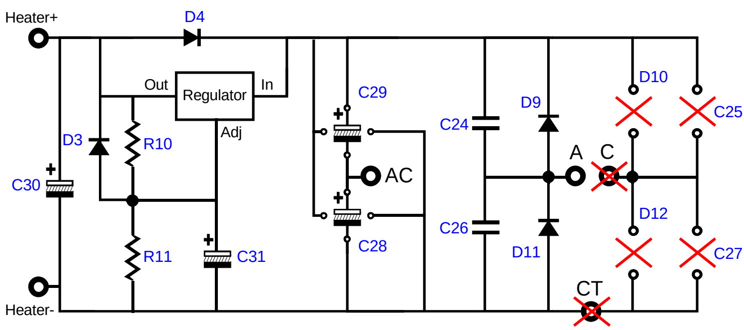

# Full-Wave Center-Tap

Capacitor C28 & C9 positive leads pointing to heatsink
Full-Wave CT Raw DC voltage = 1.414Vac - 1V




# Voltage Doubler

Capacitor C28 & C9 positive leads pointing to the right
Fullwave-Volatge-Doubler Rectification. Raw DC voltage = 2.828Vac - 2V



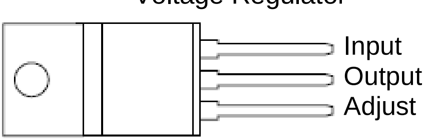

# Typical Part Values

**C24 - C27 = 0.01µf to 0.1µF Ceramic or film 50V - 100V**
**C28, C29 = 2.2kµF to 10kµF 16V**
**C30, C31 = 100µF to 1kµF 16V**

**D9 - D10 = MUR410G, 1N5402**
**D3, 4 = 1N4007**

**R10 = 124 1% ½W**
**(6.3V) R11 = 499 1% ½W**
**(12V) R11 = 1.07k 1% ½W**
**(12.6V) R11 = 1.13 1% ½W**

**LD1085**
Voltage Regulator



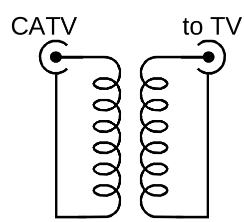

Top View

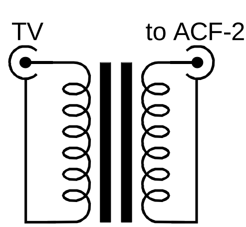
Never use a "cheater" plug to fix a hum problem; these plugs were design to promote safety, not to create a danger. Before trying any fix, make sure that all the wall sockets are wired correctly. For less than $10 you can buy an AC socket checker, which although not capable of revealing all miswires, can expose many wiring problems. A good second test procedure is to detach all the signal inputs and all the output connections from the line-stage buffer. Then measure the AC voltage between the line-stage amplifier's chassis and the house's ground. Then measure the chassis ground to the first signal source's ground on its output RCA jack (while the signal source is turned on). If it reads more than a few volts, try reversing the signal source's plug orientation as it plugs into the wall socket. Use which ever orientation that results in the lowest AC voltage reading. Then do the rest with the rest of the signal sources. The results can prove far more satisfying than what would be yielded by buying thousand-dollar cables.

**RFI** Radio frequency interference can be a hassle to track down and eliminate. The air is filled with RFI from light dimmers, switching power supplies, cordless phone cradles, computers…First make sure that all contacts are clean. Second, make sure that the source of the problem actually resides in the line-stage amplifier. For example, if only one signal source suffers from RFI noise, make sure that it is normally RFI free. In other words, attach it to another line-stage amplifier and see if the RFI persists. If it does pass this test, then try soldering small capacitors, say 100pF, from this signal source's RCA jacks to the chassis, as close as possible to the jacks: if it fails, fix the source.

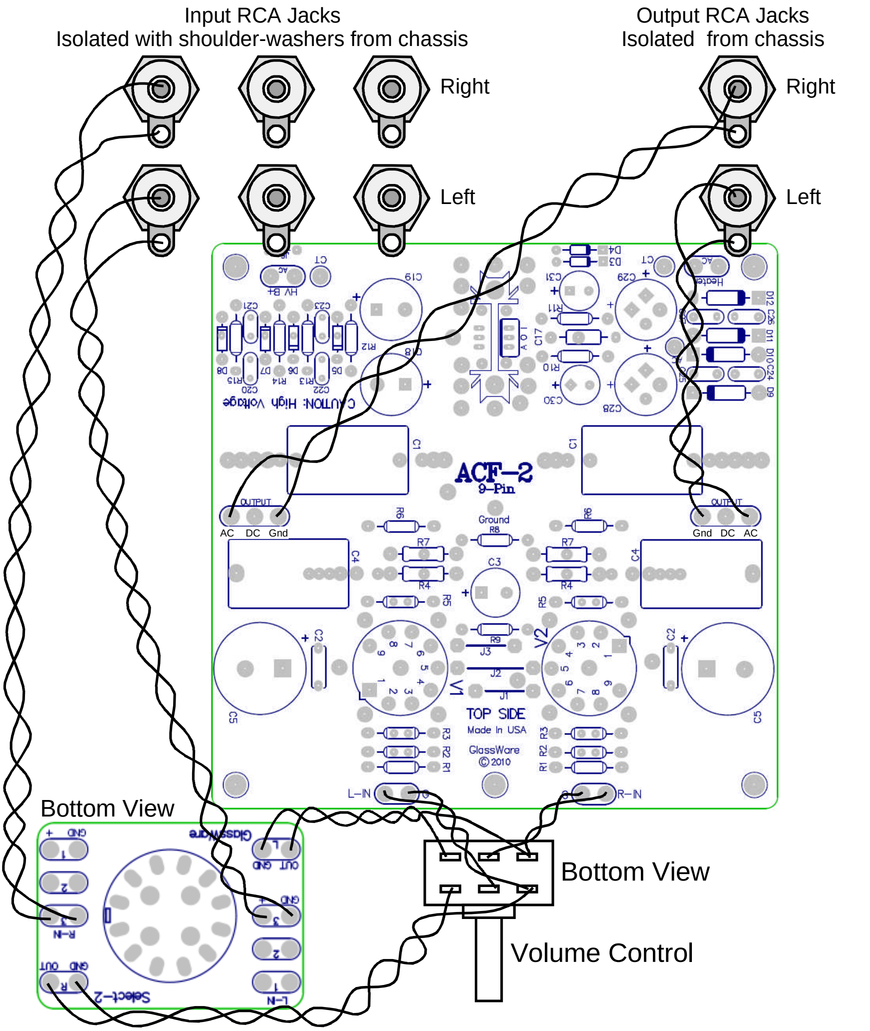
Ferrite beads can also help; try using beads on the hot lead as it leaves the input RCA jack and then again at the selector switch. Increasing the grid-stopper resistor's (R1) value, say to 1k or 10k, can also work wonders (use a carbon-composition or bulk-foil resistor or some other non-inductive resistor type).

**Terminating Resistors** Here's a cheap trick to try: at each input RCA jack, place a 100k to 1M resistor, bridging input hot and jack ground. Why? The resistor provides a path for the AC signal present at the jack, so given a choice between radiating into the chassis or going through the relatively low-impedance resistor, the AC signal chooses the latter path, reducing crosstalk.



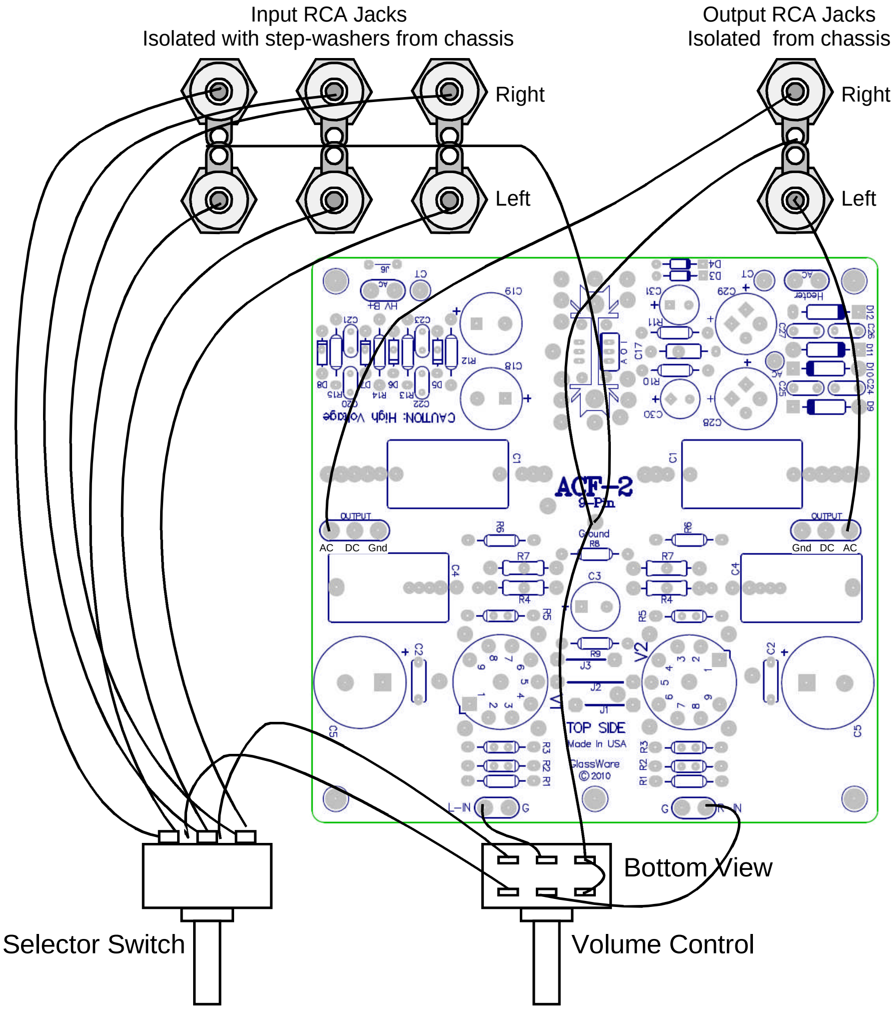




**CATV Ground** Attaching a line-stage amplifier to TV or VCR can cause huge hum problems, as the "ground" used by the connection TV cable connection my introduce hum. Isolation transformers work supremely well in this application. Be sure to use shoulder-washers to isolate the input RCA jacks from the chassis and the ACF ground. In fact, an isolation transformer can be used on all the input signals only (one transformer per channel is required, if it is located after, rather than before the selector switch). Look on the Web for more complicated solutions to the CATV hum problem, such as an isolation transformer right at the CATV input to the TV.




In this preferred physical setup, each input RCA jack gets its own pair of hot and ground wires; and the same holds true for the output RCA jacks. The six sets of twisted wire or coaxial cable travel from the input RCA jacks to a GlassWare Select-2 selector switch and then to the volume control and, finally, to the ACF-2 PCB. All RCA jacks must be isolated from the chassis with non-conducting shoulder washers. Test each jack's ground tab for shorts to the chassis, before soldering the ground wires in place. In addition, make sure that only absolutely necessary ground wires that are soldered in place. (If the volume potentiometer presents only one ground tab, then tie both of the incoming ground wires from the selector switch to this connection and send one ground wire from the potentiometer to the PCB.)

Attach both the high voltage and heater AC secondary wires to the bottom of the PCB and twist these wires into to a tight bundle that hugs the bottom of the chassis to the transformer(s).




In this typical physical setup, the input RCA jacks have all their ground tabs soldered together to a common ground wire; and the same holds true for the output RCA jacks. These two ground wires then travel back to the ACF-2 PCB; this arrangement will only work well, if the jacks are isolated from the chassis with non-conducting shoulder washers. Be sure to test each jack's ground tab first for shorts to the chassis, before soldering the ground wires in place. In addition, make sure that only absolutely necessary ground wires are soldered in place. Coaxial cable can be used for relaying the signals, but be sure to solder only one end of the shield to ground. The volume control (potentiometer) should attach to only one ground wire.

Attach both the high voltage and heater AC wires to the PCB and twist these wires into to a tight bundle that hugs the bottom of the chassis to the transformer(s).

## Assembly & Testing

**Assembly** Cleanliness is essential. Before soldering, be sure to clean both sides the PCB with 90% to 99% isopropyl alcohol. Do not use dull-looking solder; solder should shine. If it doesn't, first clean away the outer oxidation with some steel wool or a copper scouring pad. If the resistor leads look in the least gray, clean away the oxidation with either steel wool or a wire sniper's sharp edges. Admittedly, with new resistors and a fresh PCB, such metal dulling is rare; but if the parts have sat in your closet for a year or two, then expect a good amount of oxidation to have developed.

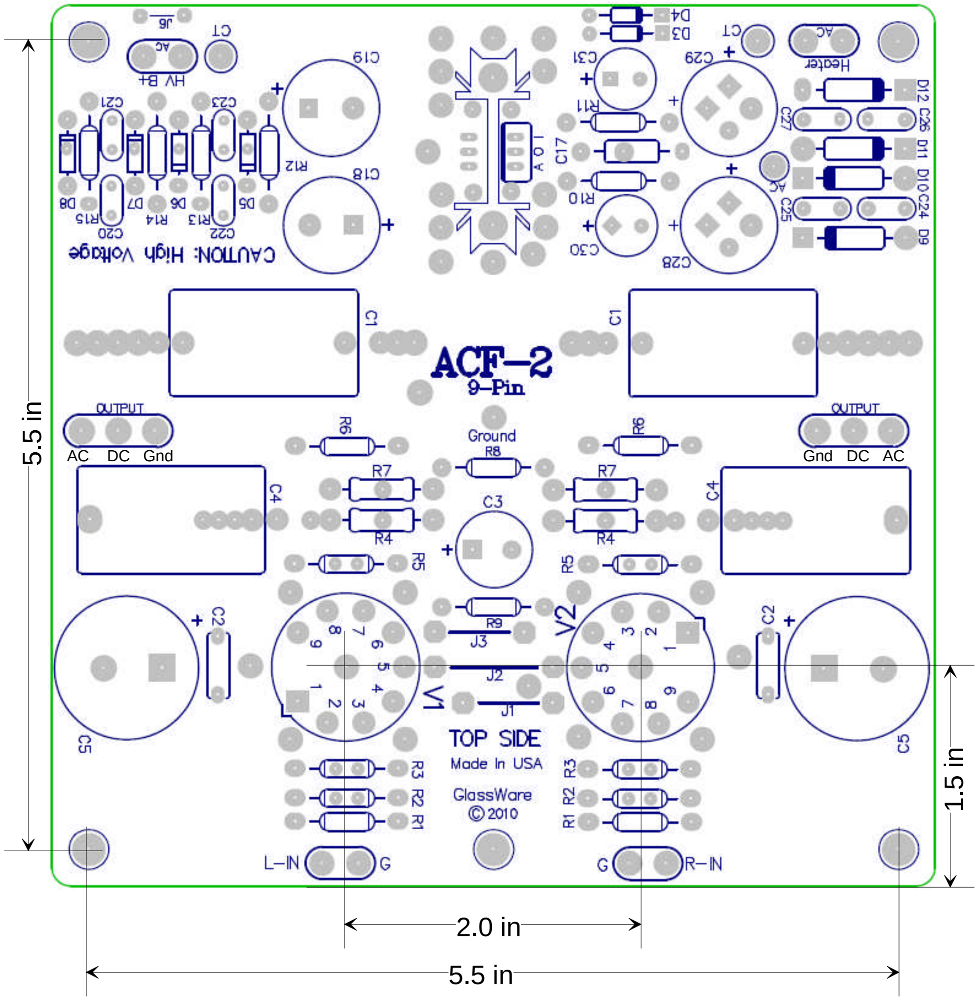
First, solder the smallest components in place, and then solder the next larger, then the largest last. Be consistent in orienting the resistors; keep all the tolerance bands on the resistor's body at the right side as you face the resistor straight on. This will pay dividends later, if you need to locate a soldered a resistor in the wrong location. Because the board is double sided, with traces and pads on each side, it is easier to solder the resistors from their top side. It is often easier to solder one tube socket pin from the top first and then to solder the rest of the socket's pin from the bottom side of PCB. As the PCB is so overbuilt, it is extremely difficult to remove an incorrectly placed part. Be especially sure to confirm all the electrolytic capacitor and power supply connections are orientated correctly, as a reversed polarized capacitor can easily vent (or even explode) when presented with high-voltage. Confirm twice, solder once. By the way, the tube sockets must be soldered to the PCB's topside, but all the remaining parts can be soldered to the bottom side. Thus, the ACF-2 PCB can be used with the tubes protruding from holes in the chassis top plate, with the all the other tall parts not interfering; be sure to use all five standoffs.

**Testing** Before testing, visually inspect the PCB for breaks in symmetry between left and right sides. Wear safety eye goggles, which is not as pantywaist a counsel as it sounds, as a venting electrolytic capacitor will spray hot caustic chemicals. Make a habit of using only one hand, with the other hand behind your back, while attaching probes or handling high-voltage gear, as a current flow across your chest can result in death. In addition, wear rubber-soled shoes and work in dry environment. Remember, safety first, second, and last.

1. Attach only the heater power supply, leaving the high-voltage leads unattached and electrical tape shrouded, with no tubes in their sockets.
2. Use a variac and slowly bring up the AC voltage feeding the power supply, while looking for smoke or part discoloration or bulging.
3. Measure the heater voltage pins 4 & 5 without and with the tube.
4. Next, power down the heater power supply and attach the high-voltage windings and insert the tubes in their sockets.
5. Attach the power transformer to a variac and slowly bring up the AC voltage.
6. Measure the voltage across ground and capacitors C4 & C5. If the two channels differ by more than 10Vdc, try switching tubes from one channel to the other. If the imbalance does not follow the tubes, there is a problem, probably a misplaced part.

Only after you are sure that both heater and B-plus power supplies are working well, should you attach the ACF-2 to a power amplifier.

# Top Side ACF-2 PCB Mechanical Layout




## Let me know what you think

If you would like to see some new audio PCB or kit or recommend a change to an existing product or if you need help figuring out the heater jumper settings or cathode resistor values, drop me a line by e-mail to the address on the back cover (begin the subject line with either “Aikido” or “tube” or the spam filters are sure to eat your message).

| Tube | mu | rp | R2 & R5 | Ik(mA) | B+/- | Wp | Gain | Gain dB | Zo |
|---|---|---|---|---|---|---|---|---|---|
| 6AQ8 | 57 | 9700 | 100 | 10.0 | 150 | 1.49 | 0.97 | -0.30dB | 263 |
| 6BK7 | 43 | 4600 | 200 | 10.0 | 150 | 1.48 | 0.96 | -0.40dB | 298 |
| 6BQ7 | 38 | 5900 | 191 | 10.0 | 150 | 1.48 | 0.95 | -0.45dB | 334 |
| 6BS8 | 36 | 5000 | 220 | 10.0 | 150 | 1.48 | 0.95 | -0.47dB | 346 |
| 6CG7 | 20.5 | 10200 | 583 | 3.0 | 75 | 0.22 | 0.91 | -0.81dB | 1009 |
| 6CG7 | 21.1 | 8960 | 397 | 5.0 | 100 | 0.49 | 0.91 | -0.79dB | 767 |
| 6CG7 | 21 | 9250 | 626 | 5.0 | 125 | 0.61 | 0.91 | -0.79dB | 1000 |
| 6CG7 | 20.8 | 9840 | 1000 | 4.5 | 150 | 0.65 | 0.91 | -0.80dB | 1386 |
| 6CG7 | 21.4 | 8370 | 470 | 7.3 | 150 | 1.07 | 0.91 | -0.78dB | 807 |
| 6CG7 | 21.9 | 7530 | 243 | 10.0 | 150 | 1.48 | 0.92 | -0.76dB | 548 |
| 6CG7 | 21.8 | 7680 | 352 | 10.0 | 175 | 1.71 | 0.92 | -0.77dB | 659 |
| 6DJ8 | 30.2 | 3670 | 182 | 5.0 | 50 | 0.25 | 0.94 | -0.56dB | 290 |
| 6DJ8 | 30.7 | 2870 | 124 | 10.0 | 75 | 0.74 | 0.94 | -0.55dB | 208 |
| 6DJ8 | 30 | 2960 | 205 | 10.0 | 100 | 0.98 | 0.94 | -0.56dB | 291 |
| 6DJ8 | 29.6 | 3060 | 291 | 10.0 | 125 | 1.22 | 0.94 | -0.57dB | 378 |
| 6DJ8 | 28.6 | 3980 | 673 | 5.0 | 125 | 0.61 | 0.93 | -0.59dB | 780 |
| 6DJ8 | 28.3 | 4080 | 845 | 5.0 | 150 | 0.73 | 0.93 | -0.59dB | 951 |
| 6DJ8 | 28.9 | 3400 | 481 | 8.0 | 150 | 1.17 | 0.94 | -0.58dB | 575 |
| 6FQ7 | See 6CG7 | | | | | | | | |
| 6GM8 | 14 | 3400 | 187 | 2.0 | 12 | 0.02 | 0.87 | -1.16dB | 388 |
| 6H30 | 15.4 | 1140 | 69 | 20.0 | 50 | 0.97 | 0.89 | -1.06dB | 131 |
| 6H30 | 15.9 | 1040 | 74 | 30.0 | 75 | 2.18 | 0.89 | -1.03dB | 128 |
| 6H30 | 15.4 | 1310 | 221 | 20.0 | 100 | 1.91 | 0.88 | -1.06dB | 284 |
| 6H30 | 15.4 | 1380 | 294 | 20.0 | 125 | 2.38 | 0.88 | -1.06dB | 356 |
| 6H30 | 15 | 1670 | 530 | 15.0 | 150 | 2.13 | 0.88 | -1.09dB | 597 |
| 6N1P | 39.8 | 12200 | 328 | 3.0 | 100 | 0.30 | 0.95 | -0.43dB | 612 |
| 6N1P | 36 | 9480 | 221 | 5.0 | 125 | 0.62 | 0.95 | -0.47dB | 464 |
| 6N1P | 35 | 956 | 642 | 5.0 | 150 | 0.73 | 0.95 | -0.48dB | 650 |
| 6N27P | See 6GM8 | | | | | | | | |
| 9AQ8 | See 6AQ8 | | | | | | | | |
| 12AT7 | 60 | 15000 | 270 | 3.7 | 100 | 0.37 | 0.97 | -0.29dB | 507 |
| 12AU7 | 17 | 9560 | 427 | 2.5 | 50 | 0.12 | 0.89 | -0.97dB | 907 |
| 12AU7 | 16.6 | 9570 | 741 | 3.0 | 75 | 0.22 | 0.89 | -0.99dB | 1214 |
| 12AU7 | 16.7 | 9130 | 768 | 4.0 | 100 | 0.39 | 0.89 | -0.99dB | 1214 |
| 12AU7 | 17.9 | 7440 | 336 | 8.0 | 125 | 0.98 | 0.90 | -0.92dB | 693 |
| 12AU7 | 18.1 | 7120 | 328 | 10.0 | 150 | 1.47 | 0.90 | -0.91dB | 665 |
| 12AV7 | 37 | 6100 | 120 | 9.0 | 100 | 0.89 | 0.95 | -0.46dB | 273 |
| 12AV7 | 41 | 4800 | 56 | 18.0 | 150 | 2.68 | 0.95 | -0.41dB | 166 |
| 12AZ7 | See 12AT7 | | | | | | | | |
| 12AX7 | 100 | 80000 | 2000 | 0.5 | 100 | 0.02 | 0.98 | -0.18dB | 2757 |
| 12AX7 | 100 | 62500 | 1100 | 1.0 | 150 | 0.07 | 0.98 | -0.18dB | 1699 |
| 12BH7 | 16.1 | 5480 | 340 | 4.0 | 50 | 0.09 | 0.89 | -1.02dB | 624 |
| 12BH7 | 15.7 | 6090 | 706 | 4.0 | 75 | 0.14 | 0.89 | -1.04dB | 1009 |
| 12BH7 | 15.9 | 6140 | 787 | 5.0 | 100 | 0.23 | 0.89 | -1.03dB | 1085 |
| 12BH7 | 17.4 | 4870 | 383 | 10.0 | 125 | 0.59 | 0.90 | -0.95dB | 614 |
| 12BH7 | 18.4 | 4300 | 267 | 15.0 | 150 | 1.06 | 0.90 | -0.90dB | 464 |
| 12BZ7 | 100.0 | 31800 | 560 | 2.0 | 150 | 0.15 | 0.98 | -0.17dB | 866 |
| 12DJ8 | See 6DJ8 | | | | | | | | |
| 12FQ7 | See 6CG7 | | | | | | | | |
| 5751 | 70 | 58000 | 1250 | 0.8 | 100 | 0.08 | 0.97 | -0.25dB | 2034 |
| 5963 | 21 | 6600 | 200 | 10.0 | 125 | 1.23 | 0.91 | -0.79dB | 478 |
| 5965 | 47 | 7250 | 220 | 8.2 | 150 | 1.22 | 0.96 | -0.36dB | 363 |
| 6072 | 44 | 25000 | 1250 | 2.0 | 150 | 0.30 | 0.96 | -0.39dB | 1763 |
| 7119 | 21.7 | 2390 | 324 | 15.0 | 150 | 2.18 | 0.92 | -0.77dB | 411 |
| ECC81 | See 12AT7 | | | | | | | | |
| ECC82 | See 12AU7 | | | | | | | | |
| ECC83 | See 12AX7 | | | | | | | | |
| ECC85 | See 6AQ8 | | | | | | | | |
| ECC86 | See 6GM8 | | | | | | | | |
| ECC88 | See 6DJ8 | | | | | | | | |

| Resistance | Imax mA | Vmax | Wattage | F3 150µF | F3 270µF |
|---|---|---|---|---|---|
| 100 | 100mA | 10V | 1W | 10.61Hz | 5.89Hz |
| 200 | 70mA | 14V | 1W | 5.31Hz | 2.95Hz |
| 300 | 57mA | 17V | 1W | 3.54Hz | 1.96Hz |
| 470 | 46mA | 21V | 1W | 2.26Hz | 1.25Hz |
| 680 | 38mA | 25V | 1W | 1.56Hz | 0.87Hz |
| 1000 | 31mA | 31V | 1W | 1.06Hz | 0.59Hz |
| 1600 | 43mA | 69V | 3W | 0.66Hz | 0.37Hz |
| 2000 | 39mA | 77V | 3W | 0.53Hz | 0.29Hz |
| 3000 | 32mA | 95V | 3W | 0.35Hz | 0.2Hz |
| 3900 | 28mA | 108V | 3W | 0.27Hz | 0.15Hz |
| 6800 | 21mA | 143V | 3W | 0.16Hz | 0.09Hz |
| 10000 | 14mA | 170V | 3W | 0.11Hz | 0.06Hz |

| Resistor | Voltage Drop Against Current | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.90 | 1.00 |
| 200 | 0.20 | 0.40 | 0.60 | 0.80 | 1.00 | 1.20 | 1.40 | 1.60 | 1.80 | 2.00 |
| 300 | 0.30 | 0.60 | 0.90 | 1.20 | 1.50 | 1.80 | 2.10 | 2.40 | 2.70 | 3.00 |
| 470 | 0.47 | 0.94 | 1.41 | 1.88 | 2.35 | 2.82 | 3.29 | 3.76 | 4.23 | 4.70 |
| 680 | 0.68 | 1.36 | 2.04 | 2.72 | 3.40 | 4.08 | 4.76 | 5.44 | 6.12 | 6.80 |
| 1000 | 1.00 | 2.00 | 3.00 | 4.00 | 5.00 | 6.00 | 7.00 | 8.00 | 9.00 | 10.00 |
| 1600 | 1.6 | 3.2 | 4.8 | 6.4 | 8.0 | 9.6 | 11.2 | 12.8 | 14.4 | 16.0 |
| 2000 | 2.0 | 4.0 | 6.0 | 8.0 | 10.0 | 12.0 | 14.0 | 16.0 | 18.0 | 20.0 |
| 3000 | 3.0 | 6.0 | 9.0 | 12.0 | 15.0 | 18.0 | 21.0 | 24.0 | 27.0 | 30.0 |
| 3900 | 3.9 | 7.8 | 11.7 | 15.6 | 19.5 | 23.4 | 27.3 | 31.2 | 35.1 | 39.0 |
| 6800 | 6.8 | 13.6 | 20.4 | 27.2 | 34.0 | 40.8 | 47.6 | 54.4 | 61.2 | 68.0 |
| 10000 | 10.0 | 20.0 | 30.0 | 40.0 | 50.0 | 60.0 | 70.0 | 80.0 | 90.0 | 100.0 |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

Current in mA

| Resistor | Voltage Drop Against Current | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 1.10 | 1.20 | 1.30 | 1.40 | 1.50 | 1.60 | 1.70 | 1.80 | 1.90 | 2.00 |
| 200 | 2.20 | 2.40 | 2.60 | 2.80 | 3.00 | 3.20 | 3.40 | 3.60 | 3.80 | 4.00 |
| 300 | 3.30 | 3.60 | 3.90 | 4.20 | 4.50 | 4.80 | 5.10 | 5.40 | 5.70 | 6.00 |
| 470 | 5.17 | 5.64 | 6.11 | 6.58 | 7.05 | 7.52 | 7.99 | 8.46 | 8.93 | 9.40 |
| 680 | 7.48 | 8.16 | 8.84 | 9.52 | 10.20 | 10.88 | 11.56 | 12.24 | 12.92 | 13.60 |
| 1000 | 11.00 | 12.00 | 13.00 | 14.00 | 15.00 | 16.00 | 17.00 | 18.00 | 19.00 | 20.00 |
| 1600 | 17.60 | 19.20 | 20.80 | 22.40 | 24.00 | 25.60 | 27.20 | 28.80 | 30.40 | 32.00 |
| 2000 | 22.00 | 24.00 | 26.00 | 28.00 | 30.00 | 32.00 | 34.00 | 36.00 | 38.00 | 40.00 |
| 3000 | 33.00 | 36.00 | 39.00 | 42.00 | 45.00 | 48.00 | 51.00 | 54.00 | 57.00 | 60.00 |
| 3900 | 42.90 | 46.80 | 50.70 | 54.60 | 58.50 | 62.40 | 66.30 | 70.20 | 74.10 | 78.00 |
| 6800 | 74.80 | 81.60 | 88.40 | 95.20 | 102.00 | 108.80 | 115.60 | 122.40 | 129.20 | 136.00 |
| 10000 | 110.00 | 120.00 | 130.00 | * | * | * | * | * | * | * |
| | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |

Current in mA

| Resistor | Voltage Drop Against Current | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 2.10 | 2.20 | 2.30 | 2.40 | 2.50 | 2.60 | 2.70 | 2.80 | 2.90 | 3.00 |
| 200 | 4.20 | 4.40 | 4.60 | 4.80 | 5.00 | 5.20 | 5.40 | 5.60 | 5.80 | 6.00 |
| 300 | 6.30 | 6.60 | 6.90 | 7.20 | 7.50 | 7.80 | 8.10 | 8.40 | 8.70 | 9.00 |
| 470 | 9.87 | 10.34 | 10.81 | 11.28 | 11.75 | 12.22 | 12.69 | 13.16 | 13.63 | 14.10 |
| 680 | 14.28 | 14.96 | 15.64 | 16.32 | 17.00 | 17.68 | 18.36 | 19.04 | 19.72 | 20.40 |
| 1000 | 21.00 | 22.00 | 23.00 | 24.00 | 25.00 | 26.00 | 27.00 | 28.00 | 29.00 | 30.00 |
| 1600 | 33.60 | 35.20 | 36.80 | 38.40 | 40.00 | 41.60 | 43.20 | 44.80 | 46.40 | 48.00 |
| 2000 | 42.00 | 44.00 | 46.00 | 48.00 | 50.00 | 52.00 | 54.00 | 56.00 | 58.00 | 60.00 |
| 3000 | 63.00 | 66.00 | 69.00 | 72.00 | 75.00 | 78.00 | 81.00 | 84.00 | 87.00 | 90.00 |
| 3900 | 81.90 | 85.80 | 89.70 | 93.60 | 97.50 | 101.40 | 105.30 | 109.20 | * | * |
| 6800 | 142.80 | * | * | * | * | * | * | * | * | * |
| 10000 | * | * | * | * | * | * | * | * | * | * |
| | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |

Current in mA

* Exceeds maximum Voltage/Current