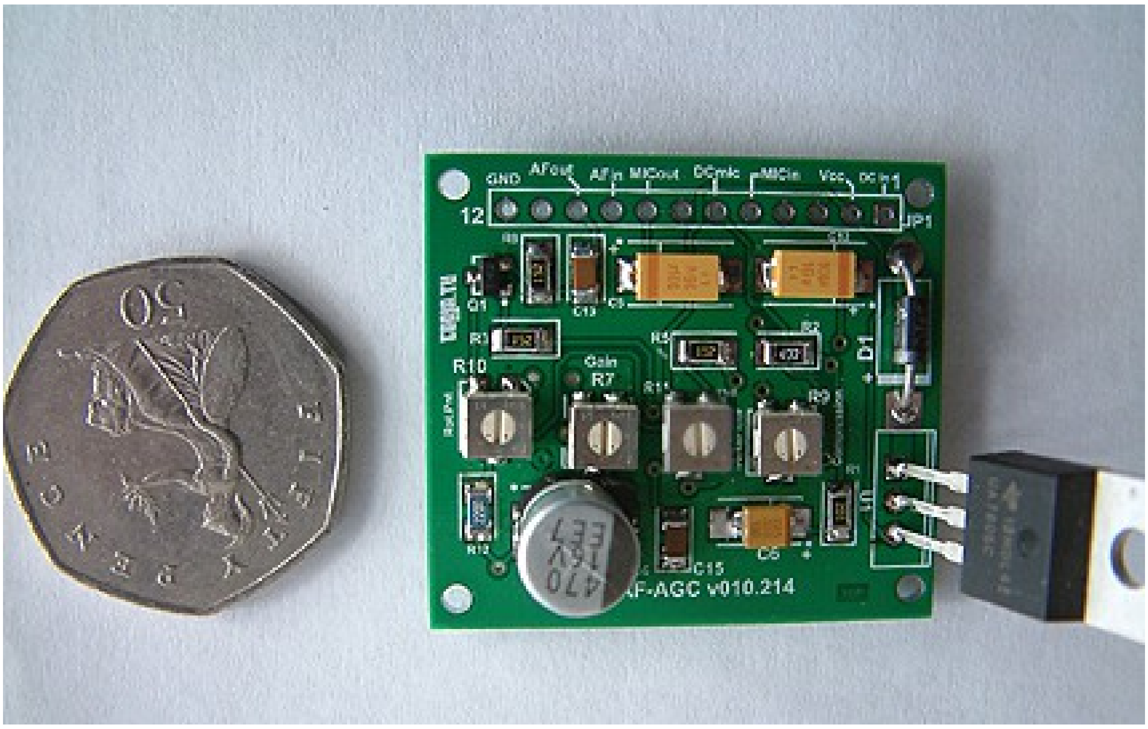
VERSATILE AUDIO AGC CIRCUIT

Dave Kenward G8AJN



Whilst we spend many happy hours perfecting our video signals, the audio often tends to be an afterthought. For our local repeater a finely adjustable compressor/limiter circuit was required and this article describes what was found to be one of the most versatile solutions. With an independent built-in high gain pre-amplifier almost any microphone can also be used.

Popularly called VOGADs, automatic audio level controllers are essential for ATV use where a bench microphone can often be too far from the speaker while he is correctly positioned for the camera and will often be in a noisy (PA fans etc.) environment in which a poorly adjusted AGC circuit will raise the background to full volume when not speaking. Even a headset microphone can benefit from compression to avoid over-modulation. A solution would require a microphone amplifying chip containing a compressor with adjustable upper and lower compression points to allow more accurate settings to suit individual conditions would be ideal.

Analog Devices have come up with the solution in a low cost device. The SSM2166 is a complete audio and microphone signal conditioning system on a single integrated circuit. It provides amplification, RMS detection, limiting, variable compression, and downward expansion.
An integral voltage-controlled amplifier (VCA) provides up to 60 dB of gain in the signal path with approximately 30 kHz bandwidth. Additional gain if required is provided by an input buffer/ microphone input op amp circuit that can be set anywhere from 0dB to 20 dB, for a total signal path gain of up to 80 dB.
It is, as most are these days, surface mount, packaged in a 14 pin (SOIC14) body, making it tricky for home-brew. This article presents a commercially manufactured PCB specifically to allow for home construction. Small enough to be added easily to an existing project 35mm x 40mm (approx 1.25" x 1.5"), it is a low distortion, wideband audio circuit giving sufficient output from a microphone input to drive even the rather deaf Comtech ATV transmitters.

The SSM2166 operates on a single +5 V supply at 8mA, accepts input signals up to 3v pk-pk into the VCA and will accept microphone signals into the buffer amp below 15mV, and produces output

signal levels of over 3 V p-p into loads over 5 k.
The low noise voltage-controlled amplifier (VCA) provides a gain that is dynamically adjusted by a control loop to maintain a set compression characteristic. The compression ratio is set by a single preset trimmer resistor and can be varied from 1:1 to over 15:1 relative to a user defined “rotation point”; signals above the rotation point are limited to prevent overload and eliminate “popping ” and over-modulation.

In the 1:1 compression setting, the SSM2166 can be programmed with a fixed gain of up to 20 dB; this gain is in addition to the variable gain in other compression settings.
A downward expander (noise gate) prevents amplification of noise or hum. This results in optimized signal levels in noisy environments.
The compression ratio and time constants are set with preset trimmer resistors.
The compression ratio may be varied from 1:1 (no compression) to over 15:1 via a single resistor, R9
The nominal gain of the system may be increased by the user via the on-board VCA by up to 20 dB. Additionally, the input buffer of the SSM2166 can be configured to provide fixed gains of 0 dB to 20 dB with R2.

Input signals below the threshold are downward expanded; that is, a –1 dB change in the input signal level causes approximately a –3 dB change in the output level. As a result, the gain of the system is small for very small input signal levels, even though it may be quite large for small input signals above the downward expansion threshold which is set externally by the user via R11 at Pin 9 .

SSM2166 SIGNAL PATH.
Figure 1 illustrates the block diagram of the SSM2166. The audio input signal is processed by the input buffer and then by the VCA. The input buffer presents an input impedance of approximately 180 k to the source. A DC voltage of approximately 1.5 V is present at AUDIO +IN (Pin 7 of the SSM2166),requiring the use of a blocking capacitor (C1) for ground referenced sources. . The input buffer is a unity-gain stable amplifier that can drive the low impedance input of the VCA.
The VCA is a low distortion, variable-gain amplifier whose gain is set by the side-chain control circuitry. The input to the VCA is a virtual ground in series with approximately 1 k . An external blocking capacitor (C5) is used between the buffer’s output and the VCA input. The 1 k impedance between amplifiers determines the value of this capacitor, which is 10 μF.
The VCA amplifies the input signal current flowing through C16 and converts this current to a voltage at the SSM2166’s output pin (Pin 13). The net gain from input to output can be as high as 60 dB (without additional buffer gain),depending on the gain set by the control circuitry.
The gain of the VCA at the rotation point is set by the value of a preset resistor R7 connected between Pin 2 and GND.
The AGC range of the SSM2166 can be as high as 60 dB.
The VCA pin (Pin 3) on the SSM2166 is the non-inverting input terminal to the VCA. The inverting input of the VCA is also available on the SSM2166’s Pin 4 (VCAIN) and exhibits an input impedance of 1 k, as well. As a result, this pin can be used for differential inputs or for the elimination of grounding problems by connecting a capacitor whose value equals that used in series with the VCA IN R pin, to ground.
The output impedance of the SSM2166 is typically less than 75R, and the external load on Pin 13 should be >5 k.
The nominal output dc voltage of the device is approximately 2.2 V. This DC is used to bias the emitter follower transistor BC848. Any low noise high gain NPN audio transistor should be fine in this location.

The bandwidth of the SSM2166 is quite wide at all gain settings. The upper 3dB point is

approximately 30 kHz at gains as high as 60 dB (using the input buffer for additional gain, circuit bandwidth is unaffected).
The lower 3 dB cut-off frequency of the SSM2166 is set by the input impedance of the VCA (1 k) and C5. While the noise of the input buffer is fixed, the input referred noise of the VCA is a function of gain. The VCA input noise is designed to be a minimum when the gain is at a maximum, thereby optimizing the usable dynamic range of the part.

LEVEL DETECTOR.
The SSM2166 incorporates a full-wave rectifier and a patent pending true rms level detector circuit whose averaging time constant is set by an external capacitor C12 connected to pin 8. For optimal low frequency operation of the level detector down to 10 Hz, the value of the capacitor should be 2.2 μF.
Some experimentation with larger values for C12 may be necessary to reduce the effects of excessive low frequency ambient background noise. The value of the averaging capacitor affects sound quality: too small a value for this capacitor may cause a "pumping effect" for some signals, while too large a value can result in slow response times to signal dynamics. Electrolytic capacitors are recommended here for lowest cost and should be in the range of 2 μF to 47 μF.
Capacitor values from 10 μF to 22 μF have been found to be more appropriate in voice-band applications, where capacitors on the low end of the range seem more appropriate for music program material.
The rms detector filter time constant controls both the steady-state averaging in the rms detector as well as the release time for compression; that is, the time it takes for the system gain to react when a large input is followed by a small signal. The attack time, the time it takes for the gain to be reduced when a small signal is followed by a large signal, is controlled partly by capacitor C12 value, but is mainly controlled by internal circuitry that speeds up the attack for large level changes. This limits overload time to under 1 ms in most cases. The attack time of the RMS level detector is dependent only on C12, but the release times are linear ramps whose decay times are dependent on both C12 and the input signal step size. The rate of release is approximately 240 dB/s for a C12 of 2.2 μF, and 12 dB/s for a C12 of 22 μF.

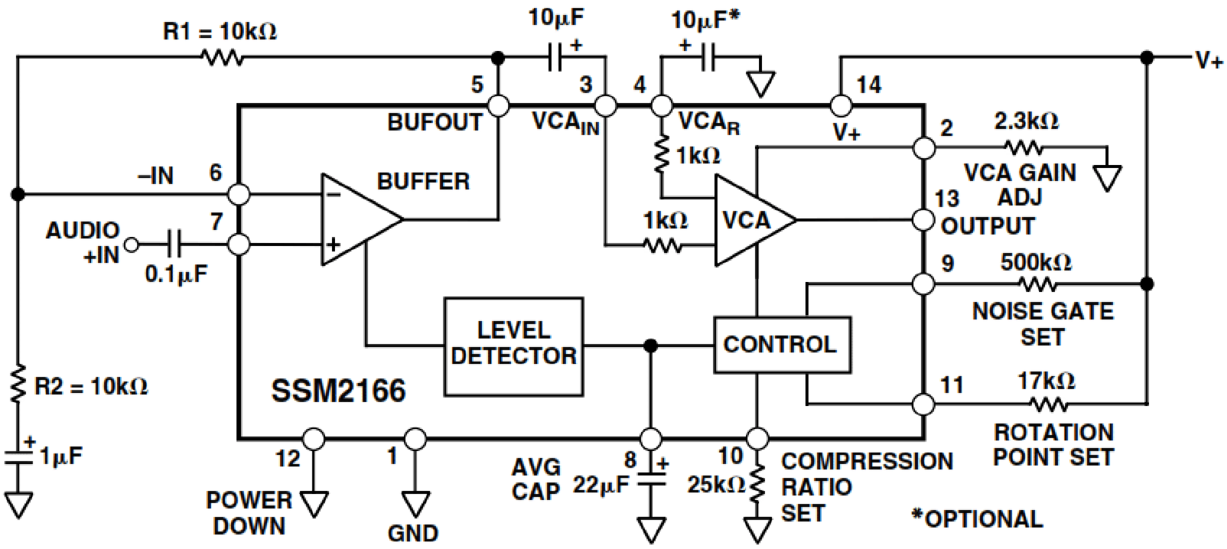


Fig 1. Block Diagram SSM2166

CONTROL CIRCUITRY.

The output of the RMS level detector is a signal proportional to the log of the true rms value of the buffer output with an added DC offset. The control circuitry subtracts a dc voltage from this signal, scales it, and sends the result to the VCA to control the gain. The VCA's gain control is logarithmic—a linear change in control signal causes a dB change in gain. It is this control law that allows linear processing of the log RMS signal to provide the flat compression characteristic.

COMPRESSION RATIO.
Changing the scaling of the control signal fed to the VCA causes a change in the circuit's compression ratio, The compression ratio can be set by R9 between pin 10 and GND.
Lowering R9 gives smaller compression ratios with values of about 17 k or less resulting in a compression ratio of 1:1. AGC performance is achieved with compression ratios between 2:1 and 15:1, and is dependent on the application. A 100 k potentiometer is used to allow this parameter to be adjusted.

ROTATION POINT
Rotation Point Set, pin 11. The rotation point may be varied from approximately 20 mV RMS to 1 V RMS. For example, 1 k would typically set the rotation point at 1 V RMS, whereas 55 k would typically set the rotation point at approximately 30 mV RMS.
Since limiting occurs for signals larger than the rotation point , the rotation point effectively sets the maximum output signal level. It is recommended that the rotation point be set at the upper extreme of the range of typical input signals so that the compression region will cover the entire desired input signal range. Occasional larger signal transients will then be attenuated by the action of the limiter.

GAIN ADJUST.
The maximum gain of the SSM2166 is set by the GAIN ADJUST pin 2 via R7.
This resistor will cause the nominal VCA gain to vary from 0 dB to approximately 20 dB, respectively.
Switching Pin 2 through 330 R or less to ground will mute the output. Either a switch connected to ground or a transistor may be used,. To avoid audible "clicks" when using this mute feature, a 10nF capacitor can be connected from Pin 2 to GND. The value of the capacitor is arbitrary and should be determined empirically, no provision for this feature has been incorporated in the pcb design.,

DOWNWARD EXPANSION THRESHOLD.
The downward expansion, or noise gate, threshold is determined via a second reference voltage internal to the control circuitry. This second reference can be varied in the SSM2166, connected between the positive supply and the NOISE GATE SET pin (Pin 9) of the SSM2166.
The downward expansion threshold may be set between 300 µV RMS and 20 mV RMS by varying the resistance value between Pin 9 and the supply voltage. Like the ROTATION ADJUST, the downward expansion threshold is inversely proportional to the value of this resistance: setting this resistance to 1 M sets the threshold at approximately 250 µV RMS, whereas a 10 k resistance sets the threshold at approximately 20 mV RMS. In general, the downward expansion threshold should be set at the lower extreme of the desired range of the input signals, so that signals below this level will be attenuated. Best adjusted to suit personal taste.

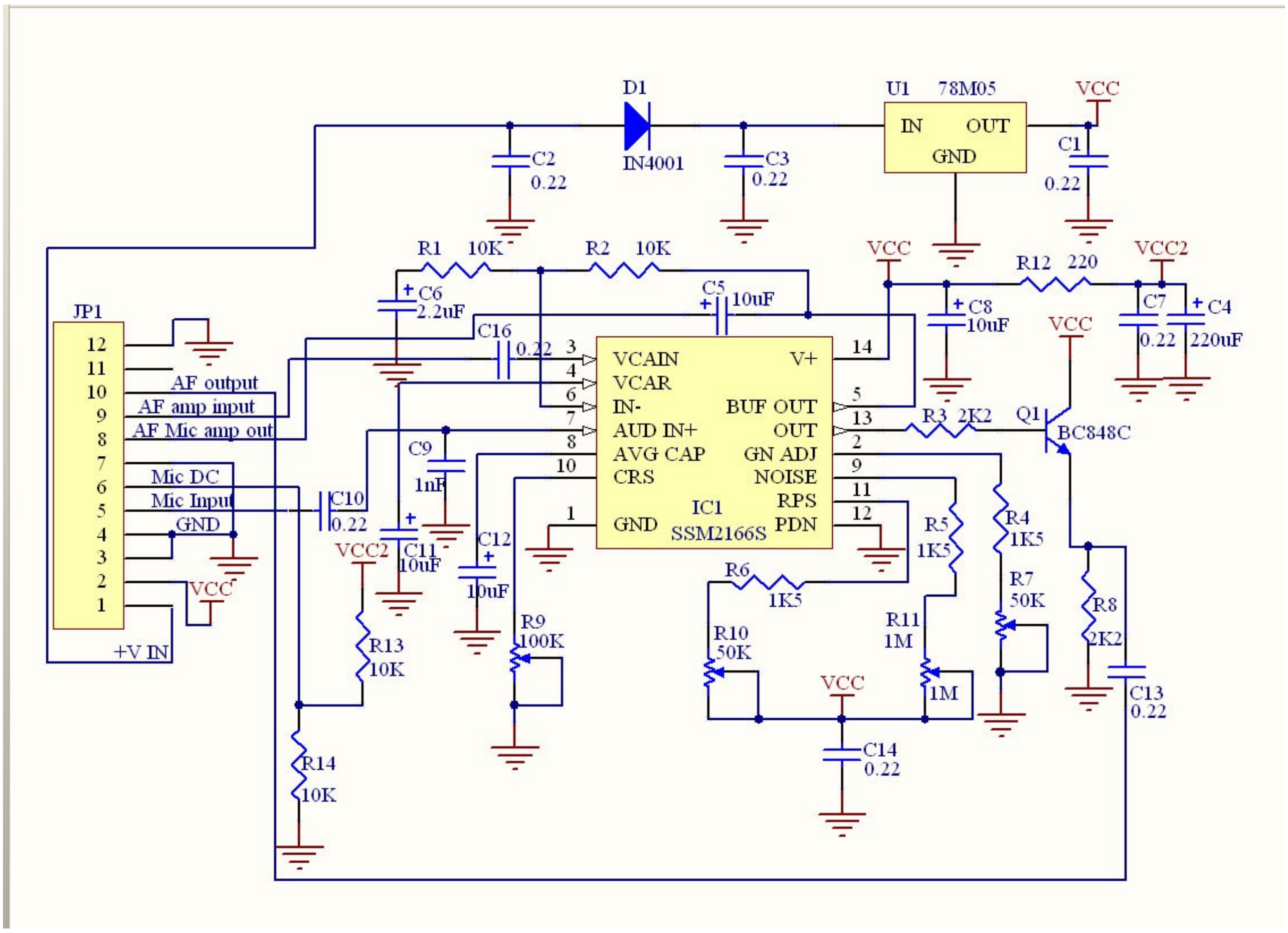


Fig 2. Complete circuit diagram

Q1 has been added to give a buffered output for various loads. C13 can be increased for lower output impedance loads. C15 is no longer required.

PRINTED CIRCUIT BOARD CONSIDERATIONS.

Since the SSM2166 is capable of wide bandwidth operation and can be configured for as much as 80 dB of gain, reasonable care must be exercised in the positioning and cabling of the PCB that contains the IC and its associated components. The following applications hints should be considered and/or followed:

(1) In some high system gain applications, the shielding of input wires to minimize possible feedback from the output of the SSM2166 back to the input circuit may be necessary.

(2) A single-point ("star") ground implementation is recommended in addition to maintaining short lead lengths.

(3) The internal buffer of the SSM2166 was designed to drive only the input of the internal VCA and its own feedback network.

Stray capacitive loading to ground from the buffer output in excess of 5 pF to 10 pF can cause excessive phase shift and can lead to circuit instability.

(4)When using high impedance input sources (>5 k), system gains in excess of 60 dB are not recommended. This configuration is rarely appropriate, as virtually all high impedance inputs provide larger amplitude signals that do not require as much amplification.

(5) When using high impedance sources, however, it can be advantageous to shunt the source with a capacitor C9 to ground at the input pin of the IC (Pin 7) to lower the source impedance at high frequencies, a capacitor with a value of 1000pF is a good starting value and sets a low-pass corner at 31kHz for 5k sources. In applications where the source ground is not as "clean" as would

be desirable, a capacitor from the VCA input to the source ground might prove beneficial. This capacitor is used in addition to the grounded capacitor used in the feedback around the buffer, assuming that the buffer is configured for gain.

. This connection makes the source ground noise appear as a common-mode signal to the VCA, allowing the common-mode noise to be rejected by the VCA's differential input circuitry. C11 can also be useful in reducing ground loop problems and in reducing noise coupling from the power supply by balancing the impedances connected to the inputs of the internal VCA.

The SSM2166 has an input buffer that may be adjusted with R2. Set to suit the type of input or when the overall gain required exceeds 20 dB, the maximum user-selectable gain of the VCA. For example, the desired output of 500 mV for an input around 15 mV, requires a total gain of 30 dB.

The 7805 regulator is used to allow wide ranges of input DC supply. As the whole board uses less than 25mA an external 5v regulated supply could be used and the regulator and diode replaced by links. The supply to the SSM2166 must not exceed 5v.

If a fixed usage is planned it is possible to reduce expense by fitting fixed resistors in place of several of the preset trimmers. If you are considering this here are some suggestions...

Pin 2: Gain. For low level signal sources, the VCA should be set to maximum gain using a 20 k resistor. Setting the VCA gain to its maximum can also be achieved by leaving the pin in an open condition (no connection).

Pin 6: Inverting Input to the Buffer. A 10 k feedback resistor R2 from the buffer output Pin 5 to this input pin, and a resistor R1, from this pin through a 1 µF capacitor to ground gives gains of 6 dB to 20 dB for R1 = 10 k to 1.1 k.

Pin 8 : Detector Averaging Capacitor. A capacitor, 2.2 µF to 22 µF, to ground from this pin is the averaging capacitor for the detector circuit.

Pin 9: Noise Gate Threshold Set Point. A resistor to V+ sets the level below which input signals are downward expanded. For a 0.7 mV threshold, the resistor value is approximately 380 k. Increasing the resistor value reduces the threshold.

Pin 11: Rotation Point Set Pin. This is set by a resistor to the positive supply. This resistor together with the gain adjust pin determines the onset of limiting. A typical value for this resistor is 17 k for a 100 mV "rotation point." Increasing the resistor value reduces the level at which limiting occurs.

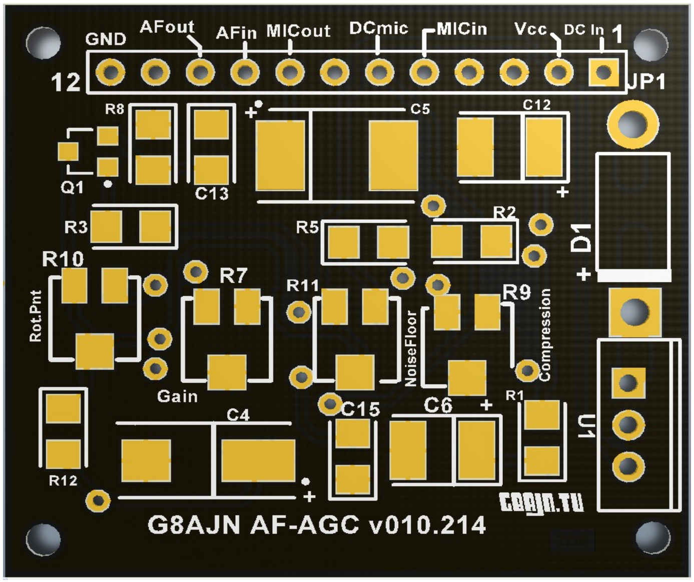


Fig 3. Board Topside overlay

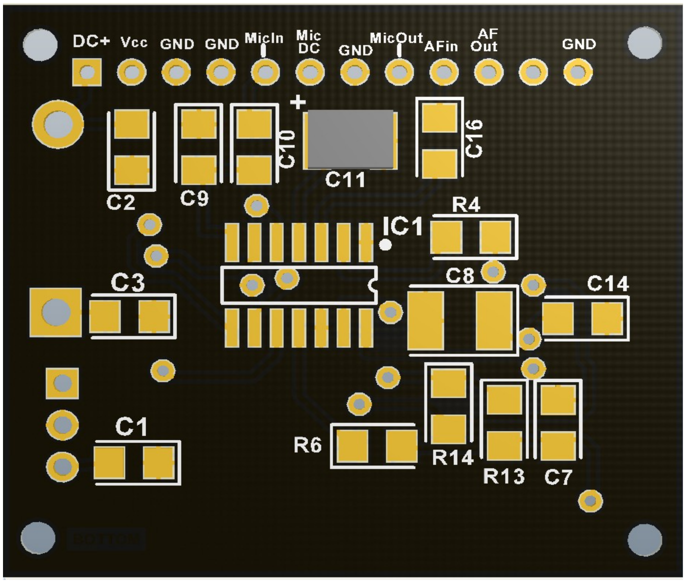


Fig 4. Board Bottom overlay

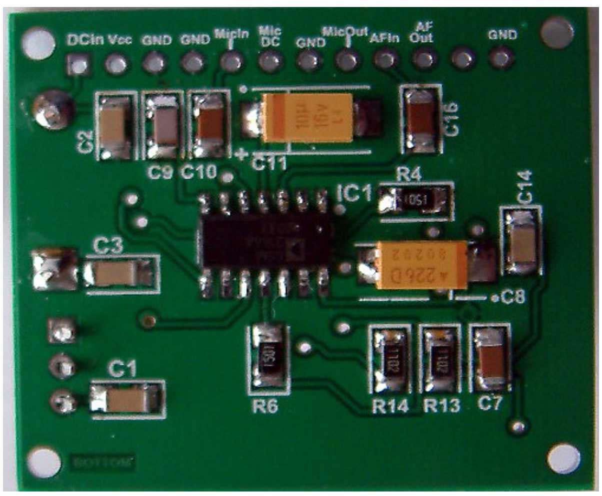


Fig 5. Bottom View.

Comment	Pattern	Qty	Component Number	Part Number
1nF	1206	1	C9	F1759337 R758-0354
0.22	1206	9	C1, C3, C10, C13, C16	C15 not used
			C2, C7, C14	F 1759362
2.2uF	C	1	C6	F 1457419
10uF	D	4	C5,C8,C11,C12	F 1432447
220uF	E	1	C4	F 2326089
220R	1206	1	R12	F 2139380
1K5	1206	5	R4, R5, R6	F 2331868
10K	1206	3	R1, R13, R14	F 2057856
2K2	1206	2	R3, R8	F233145 R740-9097
4K7	1206	1	R2 (or 10k for non-electret)	F 2331874
50k preset	4mm SMD	2	R7, R10	F 1520634
100k preset	4mm SMD	1	R9	R 486-7554
1M preset	4mm SMD	1	R11	R 177-419 or F1689911
L78M05	TO220V	1	U1	F 1087117
BC848C	SOT23-3	1	Q1	F 9846670
IN4001	Axial	1	D1	R 1458986
SSM2166S	SOIC14	1	IC1	R 412-888
Header, 12-Pin	2.5mm spacing	1	JP1 (optional)	**

Fig 6. Bill Of Materials

Part numbers are for guidance only. Numbers beginning with R indicate RS, F for Farnell.
(Do not include these letters when ordering from the supplier!)
*** Decoupling, other values >10mfd may be used if available.**

**** The (optional) header should be non-reversible such as the SPOX series.**
Header (socket) R 6878076 with 12way housing (plug) R 6878026 and with crimp terminal pins R 6877152. If desired a right-angle header could be used.

Presets should be 4mm SMD types (shown on the left), those with 'protruding' contacts (shown on right) are difficult to fit due to their extra lead length but can be cut to fit or the

legs can be folded under the body. Similar types in 3mm format can be fitted instead.

Do not be tempted to save money by getting the cheaper 'open' skeleton types as they fall apart too easily.

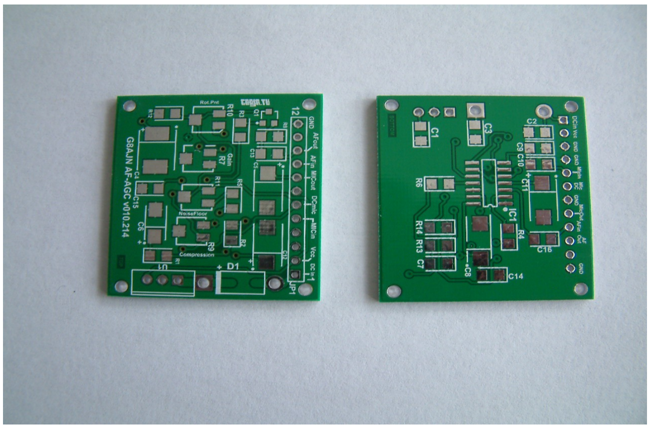


Figure 7 Top and bottom sides of the pcb

CONSTRUCTION NOTES

JP1 is a 12 way 2.5mm connector for the board including the DC input. This connector is entirely optional and wires can be directly soldered into the holes instead or individual pins may be used. To avoid the need for heat-sinking the 7805 regulator the input should be around 10 – 12v DC .
Mainly SMD components are used. Resistors are 1206, the presets are 4mm spacing although it should be possible to use 3mm with care placing them due to tracking beneath the component. Small capacitors are mostly 1206. Electroytics are intended to be SMD but wire-ended may be used by cutting the legs to 5mm and bending to an 'L' shape for soldering to the PCB solder pads. Due to the high price of tantalum capacitors, they could be used only for the cheaper 2.2uF and 10uF while the larger values could be aluminium.

With the high gains available in this circuit, sensible cabling and grounding techniques should be used and suitable screening from nearby RF sources employed.
The output of the preamp section (pin 5) is taken out to pin 8 of the connector JP1. This gives the option to feed a different source in via switching. If the facility is not needed the pins 8 and 9 can be linked together.

Pin 2 of the connector JP1 carries the 5v line to enable a test point or front panel 'ON' light..
Pin 6 of the JP1 supplies DC to run an electret microphone if required. Link pins 6 to pin5 to enable it. R13 and R14 values may be tweaked to provide sufficient voltage for individual types of microphone. Initially the values give half Vcc (2.5v) off load. But if more or less is required the values can be altered accordingly.C15 is not required in this circuit.

If you are not using a low level microphone input the value of R1 can be dropped to suit the levels likely to be encountered. Unity gain R2 = 0R (with R1 = O/C), for maximum gain R2 = 22k. I suggest a 4k7 for electret or 10k for regular magnetic microphones. A 10k could always be placed on top of the R2 10k at a later time to reduce the gain if desired.

I suggest placing the 12 way connector header JP1 (if intending to use one), but do not solder it in yet as you may need to remove it to permit fitting of the adjacent electrolytics. Do semiconductors first, followed by all other bottom-side components, then the preset trimmers, then top-side electrolytic capacitors to ensure ease of soldering. followed by the remaining top-side components. Place the 7805 last.

INITIAL SETTINGS.

My preferred method is to set all presets to mid-position. Connect microphone to pin 5 of JP1 (if electret type then link JP1 pin 6 & pin 5) and link pins 9 & 8. The audio output on pin 10 should go into an audio amplifier for monitoring via headphones. (There is often sufficient output to drive earphones). Connect the DC supply to JP1 and check for the 5v at Pin 2 of the connector . Now adjust the presets to give the type of agc/compression/limiting required. Large audio signals, line input levels for example, can bypass the front amplifier stage and go straight in onto pin 9 of JP1.

Please check with my website www.g8ajn.tv under PROJECTS menu for updates and details of purchasing these inexpensive commercially manufactured PCBs.

G8AJN.