Use of the Armadillo Intertie System 001-1016-0001-B1 Audio, Squelch, and Radio Interface Board With the Motorola MSF-5000 Repeater Station

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This document describes the interface of an Armadillo 1016 board to a Motorola MSF-5000 repeater station, the modifications required to the 1016 board to make it suitable for use with the MSF-5000, and the information required to make the radio suitable for use with an external control system.

The Motorola MSF-5000 presented a unique challenge since it is a fully integrated repeater with all station control, audio, repeater, and remote control functions included in the station's microprocessor control unit. My goal was to determine how to interface the station to an external controller, something it was not designed to do.

It turns out to be possible with some creative programming of the repeater code plug, and a willingness to give up some of the functionality available in a stand-alone configuration.

As with all modifications, make sure you are familiar with the operation of the MSF-5000 radio before attempting any of these modifications. Also, make sure the radio works properly before making any changes to the radio. It is much easier to troubleshoot before the modification.

Programming the MSF-5000 Code Plug

The radio I modified has the earlier version of the MSF-5000 microprocessor control unit. It uses an EPROM to store all the frequency data and operational parameters. To program this EPROM, you must have access to a Motorola "suitcase" programmer, and the MSF-5000 plug-in module for the programmer. These programmers are very rare, and you might have some trouble finding one. There are a number of people on the Web that do programming for $20-$100. I do not have a programmer, so I cannot program the chips myself. The EPROM is a standard 2732, so once you have a programmed chip, you can clone it with a standard ROM programmer.

There is a later version of the MSF-5000 control unit that uses a computer interface and software to program, but I do not have any experience with this type of station. I'm sure the interface would be very similar, but I do not have any information on how to program the later version stations.

Program the radio as a carrier-squelch, local control duplex base station with the Motorola software. Set it up without any repeater functions, and with no ID messages. My radio had a tone remote control module in the control unit. There is a DC remote control unit available as well. I programmed my EPROM as a DC remote control station, then removed the remote control board from the station. The station worked fine, so I have to assume the software was smart enough to detect there was no remote control board in the station.

Once you have done this, verify that the station is completely operational. If any problems are found, troubleshoot them now. Do not wait until after you install the 1016 board.

Building the 1016 Board

The 1016 board is normal with the exception of the squelch circuit and an added buffer for the squelch sense input.

The MSF-5000 has three squelch circuits. One is used for the repeater function, one is used for the remote control function, and one is used for the local speaker. Of the three, only the local squelch has the MICOR-style compensated squelch action. The repeater and remote control squelches are conventional, and do not have the variable time constant action.

I decided to use the squelch in the radio instead of building the MICOR squelch portion of the 1016 board. Refer to the schematic to see what components are omitted.

The squelch sense point on the MSF-5000 is active low. The circuit of R1, R12, and Q5 should be built in the perf-board area of the 1016 to buffer and invert the signal.

Complete the 1016 board with the parts specified for the MSF-5000.

Installing the 1016 Board in the MSF-5000 Station

All connections to the MSF-5000 are made on the main microprocessor board. This board is located in the bottom of the “flip-up” box on top of the RF unit in the MSF-5000 station. I mounted the 1016 board on standoffs in the location previously occupied by the Motorola tone remote control board.

Attach points on the microprocessor board are clearly marked. Refer to the parts layout in the MSF-5000 manual if you are unsure where to look for these points on the Microprocessor board.

Connections to the 1016 board are as follows:

1016 Pin	Signal	Connection Point in MSF
E-10	V+	+9.6 Volt Test Point
E-11	Ground	Ground Test Point
E-1	Discriminator	J-800 Pin 39
E-12	Squelch Sense	Test Point 7
E-16	TX Audio	U-838 Pin 6
E-18	PTT Buffer Out	U-813 Pin 5

PL Decoding

It is possible to use the PL decoder in the station, but to obtain the necessary signal indicating PL detection; it is necessary to decode it off the data buss of the microprocessor. The Motorola manual describes how to do this. Also, the PL code is stored in the Code Plug EPROM, so if you want to change PL's you have to re-program the station. I opted to use an external PL decoder for simplicity.

Documentation Package for Armadillo Intertie Audio, Squelch, and Radio Interface 001-1016-0001 Rev B1

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December 7, 1999

This circuit is designed to provide a standard interface between a radio and a control system. It is optimized for Armadillo Standard control systems, but can be adjusted over a large range.

Circuit Description

The circuit consists of five sections. A discriminator buffer, a squelch circuit, a receive audio buffer, a transmit audio buffer, and a PTT buffer.

U2D is an inverting buffer amplifier and low pass filter. This isolates the discriminator from the circuit and pre-processes the audio for feeding the squelch. U1 and associated components are a standard Micor squelch circuit. U1 pin 10 is the carrier sense output. This feeds the COS and MUTE output transistors Q1 and Q2; and the audio gates U3B and U3D. Receive audio is fed into the board either from the discriminator buffer, or at E3. It is then fed through the level pot into a pre-emphasis network for high frequency compensation. R25 and C16 are a 6 dB per octave pre-emphasis network with adjustable knee frequency to compliment the high frequency roll off in the receiver. U3D and U3B are the audio gates. U2B is a buffer amplifier and low pass filter. This is used to provide a low impedance source to feed the control system. De-emphasis can be added here, if necessary.

On the transmit side of the circuit, U2C is a buffer amplifier with an adjustable low pass filter. On phase modulated transmitters, R30 and C20 are optimized to both de-emphasize the audio and provide high frequency compensation. In frequency modulated transmitters, R30 is jumpered. This circuit provides a place to adjust gain and frequency response before feeding into the transmitter. It also provides isolation from the control system.

Q3 and Q4 are a simple PTT buffer. This is provided to insure that transmitters requiring high current PTT can be adequately driven by any control circuit attached to E9. In the Dillo II, for example, the PTT output is a darlington. Some transmitters want their PTT lines dropped to lower voltages than the darlington is capable of, hence the buffer.

Installation and Troubleshooting

The raw discriminator audio is fed into E1. R2, R3, and C2 adjust the gain and frequency response of this buffer to optimize its characteristics for the squelch circuit. R2 should be adjusted to present the proper impedance to avoid loading the discriminator. R3 and C2 are used to set the gain and roll off. Under proper operating conditions, there should be approximately 1 Volt P-P of noise present at U2 pin 14. C2 should be chosen for a 3 dB point of 15-20 kHz.

After leaving the input buffer, the audio is fed to the squelch circuit. This circuit was plagiarized from the Micor mobile. There is an excellent set of squelch waveforms in the Motorola manual if problems are encountered in the squelch circuit. U1 pin 10 can be measured to determine if the squelch circuit is functioning. It should be 9.6 Volts squelched, and 0 Volts unsquelched. C8 and C9 determine the characteristic of the squelch action. When the squelch is operating properly, it

will give a short burst if the signal is 20 dB quieting or more, regardless of the setting of the threshold control. If you find that the squelch setting is "touchy", or chops on voice peaks, make C9 a smaller value. If you find that the squelch action is sloppy, or that you get long burst on signals that are full quieting, make C9 a smaller value. The allowable range is 100-1000 pF. I have found 470 pF to work in almost all cases.

Next, the audio comes into the receive audio buffer. In almost all cases, this should be a unity gain stage. I usually stuff them with the values shown. If you require de-emphasis for your receive output, use a capacitor which gives a 3 dB point in the 100 to 200 Hz range. If you do not need de-emphasis, use a capacitor which provides a 3 dB point in the 10 kHz range.

In the transmitter section, R30 and C20 make up an adjustable roll off circuit for use with phase modulated transmitters. If you are using an FM transmitter instead of phase modulated, replace R30 with a wire jumper. C20 is a .1 uF for all phase modulated transmitters, and should be chosen for a 3 dB point of approximately 10 kHz for FM transmitters. On FM transmitters, if you require HF compensation, attach a capacitor across R21 to create an HF compensation network similar to the one in the receive section. This capacitor will have to be hand selected. R21 should be jumpered for most phase modulated applications.

Differences from Previous Versions of 001-1016-0001 Boards

This is the third version of this circuit. It reflects the changes made based on experiences using the board with various types of radios.

Changes from Rev. B:

1. The component values have been adjusted to more closely match the way the boards are usually used.

2. R29 has been removed from the mute circuit. This was covered in a previous service bulletin.

3. The receive high frequency compensation network has been moved to the output side of the RX LEVEL pot. This prevents the setting of the RX LEVEL pot from affecting the frequency response of the compensation network. R12 was also removed during this process.

4. The error in the PTT buffer has been re-wired in this version. It is no longer necessary to perform the modification to R31 and R34.

5. The circuit trace size has been increased to a minimum value of .020 inches. The previous version was .015 inches.

6. The copper thickness on this board is double the thickness of the previous version.

7. Silk screen and solder mask have been added to ease assembly and troubleshooting.

Assembly Notes

There are several things which are noteworthy when assembling the board.

1. The transistor pads are laid out for TO-92 case transistors. If TO-18 (metal can) transistors are used, the lead pattern is reversed from the pad pattern on the board. Be careful not to put the transistors in backward.

2. All small capacitor pads are laid out for CK-05 disk ceramic capacitors. Large electrolytic caps are laid out with .200 lead spacing.

3. The COS indicator LED (D3) must be installed in order for the mute circuit to work properly. If you don't want the COS LED, put a jumper in its place. The TX LED is optional.

4. C3 is not required if JP-1 is installed. JP-1 is installed if you are using the discriminator as the receive audio source.

5. The use of tantalum capacitors in audio circuits is not recommended. Critical capacitors are C1, C3, C18, C19, and C21. Use miniature electrolytics for these capacitors.

6. The squelch and RX Level controls are NOT referenced to chassis ground. If you mount these controls on the front panel of the radio, be sure that the low side is isolated from the chassis.

7. The HF compensation pots are value critical. Do not substitute other values.

8. There is a place on the board labelled R29. This is an error in the PC board layout. Leave R29 empty. This will not affect the operation of the circuit.

Attaching TS-32 PL Decoders to the 1016 Board

The Communications Specialists TS-32 boards work very well with this circuit. The attachment points are as follows:

Decoder Input	Attach to U2 pin 14.
Out 2	If you want PL to mute the audio, Attach OUT 2 to pin 1 of U3.
Hang Up	Use this wire to put the radio in PL. Ground for PL, open for carrier.

For use with the Dillo II controller, do not attach OUT 2 to the 1016 board. Instead, attach OUT 1 to the controller PL sense input and ground the HANG UP wire.

Parts List for Radio Interface

January 1, 1992

Item	Qty.	Reference	Part	Digi-Key Part #
1	6	C1,C3,C18,C21,C22,C24	10uF	P6248
2	1	C2	SEE TABLE	
3	3	C4,C9,C13	470pF	P4032
4	5	C5,C14,C16,C23,C25	.01uF	P4513
5	1	C6	1500pF	P4553
6	2	C7,C8	100pF	P4024
7	1	C10	4.7uF	P6263
8	1	C11	.22uF	P4529
9	1	C12	3.3uF	P6262
10	1	C15	22uF	P6249
11	1	C17	SEE TABLE	
12	1	C19	SEE TABLE	
13	1	C20	SEE TABLE	
14	3	C26,C27,C28	15pF miniature	P4014
15	1	D1	9.1V 1W Zener	1N4739A
16	1	D2	1N4004	1N4004
17	1	D3	GREEN LED	P309
18	1	D4	RED LED	P308
19	3	Q1,Q2,Q4	2N2222	PN2222A
20	1	Q3	2N2907	PN2907A
21	1	R2	SEE TABLE	
22	1	R3	SEE TABLE	
23	7	R4,R9,R13,R14,R18,R31,R33	10K	10KQ
24	1	R5	22K	22KQ
25	1	R6	27K	27KQ
26	1	R7	180K	180KQ
27	1	R8	100	100Q
28	2	R10,R28	47K	47KQ
29	6	R11,R16,R20,R32,R34,R35	1K	1KQ
30	1	R15	SEE TABLE	
31	1	R17	SEE TABLE	
32	3	R19,R22,R23	100K	100KQ
33	1	R21	SEE TABLE	
34	4	R24,R25,R27,R26	20K TRIM	CEG24 (top adj) CFG24 (side adj)
35	1	R30	SEE TABLE	
36	1	U1	M7716	Motorola Part # 51-83977M16
37	1	U2	TLO74	LF347N
38	1	U3	4066	CD4066BE
39	2		14 PIN SOCKET	A401
40	1		16 PIN SOCKET	A402

Table of Radio Specific Parts

GE MASTR II AND MASTR EXEC II

Item	Qty.	Reference	Part	Digi-Key Part#
41	1	C2	27pF	P4017
42	1	C17	47pF	P4020
43	1	C19	10uF	P6248
44	1	C20	.1uF	P4525
45	1	R2	47K	47KQ
46	1	R3	180K	180KQ
47	1	R15	100K	100KQ
48	1	R17	1K	1KQ
49	1	R30	500 OHM POT	CEG52 (top adj) CFG52 (side adj)
50	1	R21	Jumper	

EF JOHNSON FLEETCOM II AND TRANSCOM II

Item	Qty.	Reference	Part	Digi-Key Part#
41	1	C2	470pF	P4032
42	1	C17	330pF	P4030
43	1	C19	.47uF	P4533
44	1	C20	100pF	P4024
45	2	R2,R17,R21	10K	10KQ
46	1	R3	47K	47KQ
47	1	R15	33K	33KQ
48	1	R30	Jumper	

Note: Transmitter high frequency compensation is accomplished by attaching a .001 to .0047uF capacitor in parallel with R21.

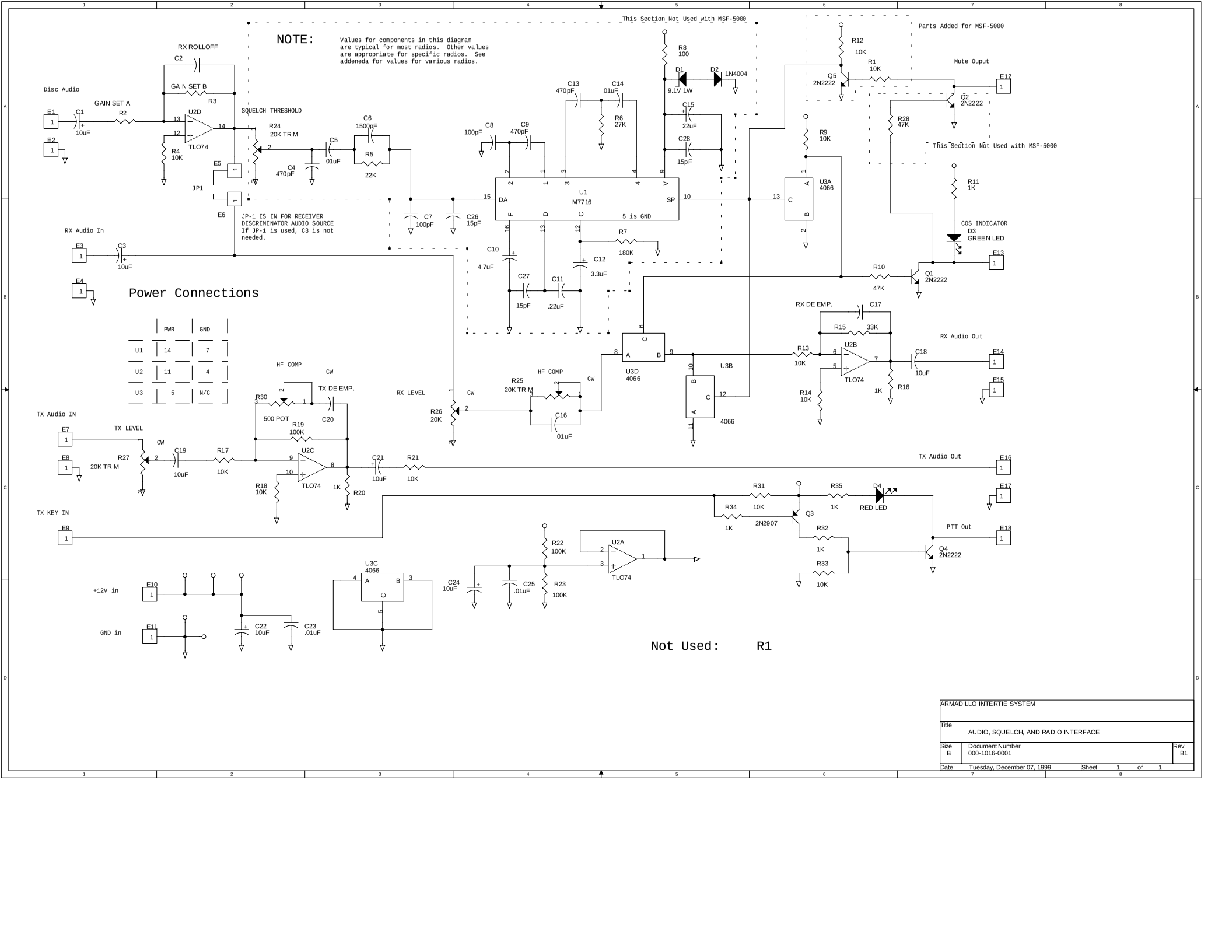
MOTOROLA MOTRAC MST

Item	Qty.	Reference	Part	Digi-Key Part#
41	1	C2	68pF	P4022
42	1	C17	470pF	P4032
43	1	C19	10uF	P6248
44	1	C20	100pF	P4024
45	2	R2,R3	100K	100KQ
46	1	R15	33K	33KQ
47	1	R17,R21	10K	10KQ
48	1	R30	Jumper	

Note: Transmitter high frequency compensation is accomplished by attaching a .001 to .0047uF capacitor in parrallel with R21.

MOTOROLA MSF-5000 REPEATER STATION

Item	Qty.	Reference	Part	Digi-Key Part #
41	2	C2,C20	100pF	P4024
42	1	C19	10uF	P6248
43	3	R2,R3,R21	100K	100KQ
44	2	R17,R19	10K	10KQ
45	1	R15	47K	47KQ
46	1	R30	Jumper	



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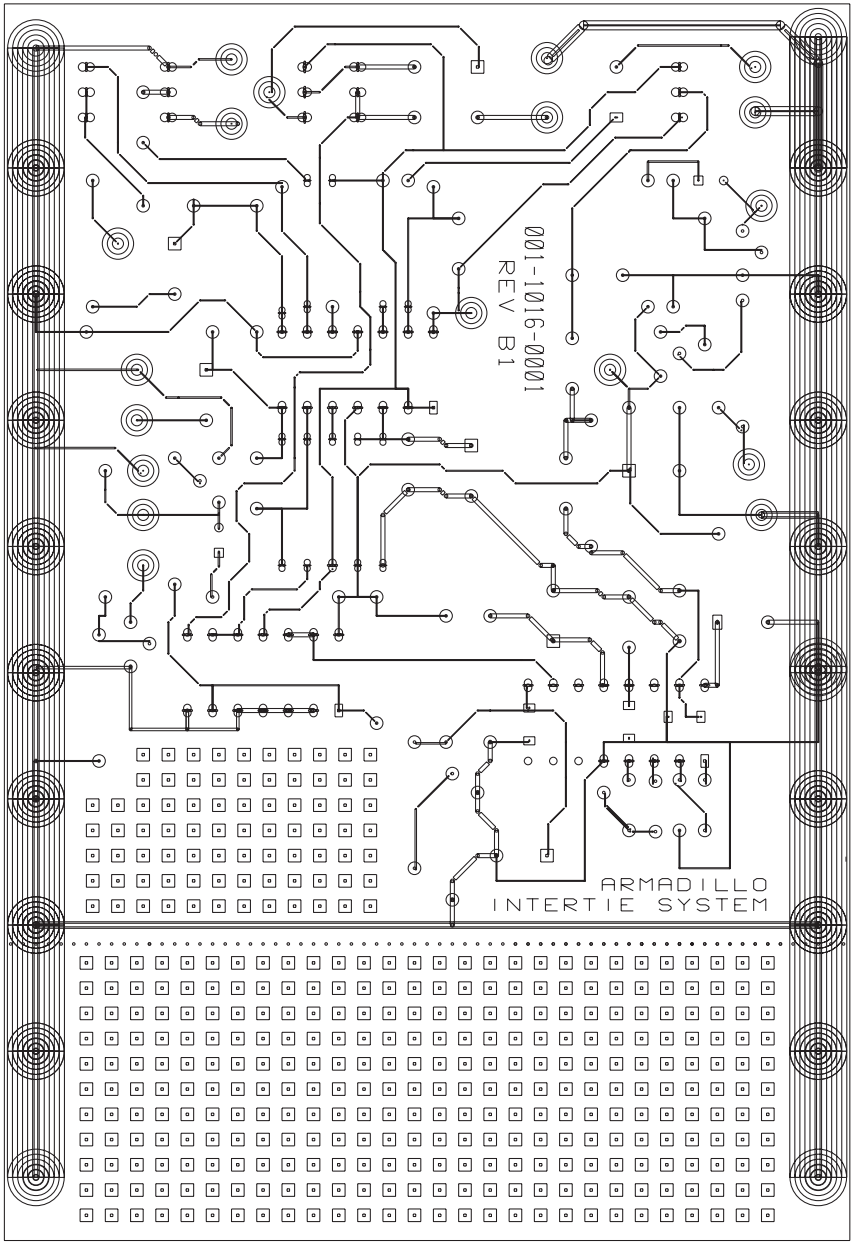
Size: B	Document Number: 000-1016-0001	Rev: B1
Date: Tuesday, December 07, 1999	Sheet 1 of 1	



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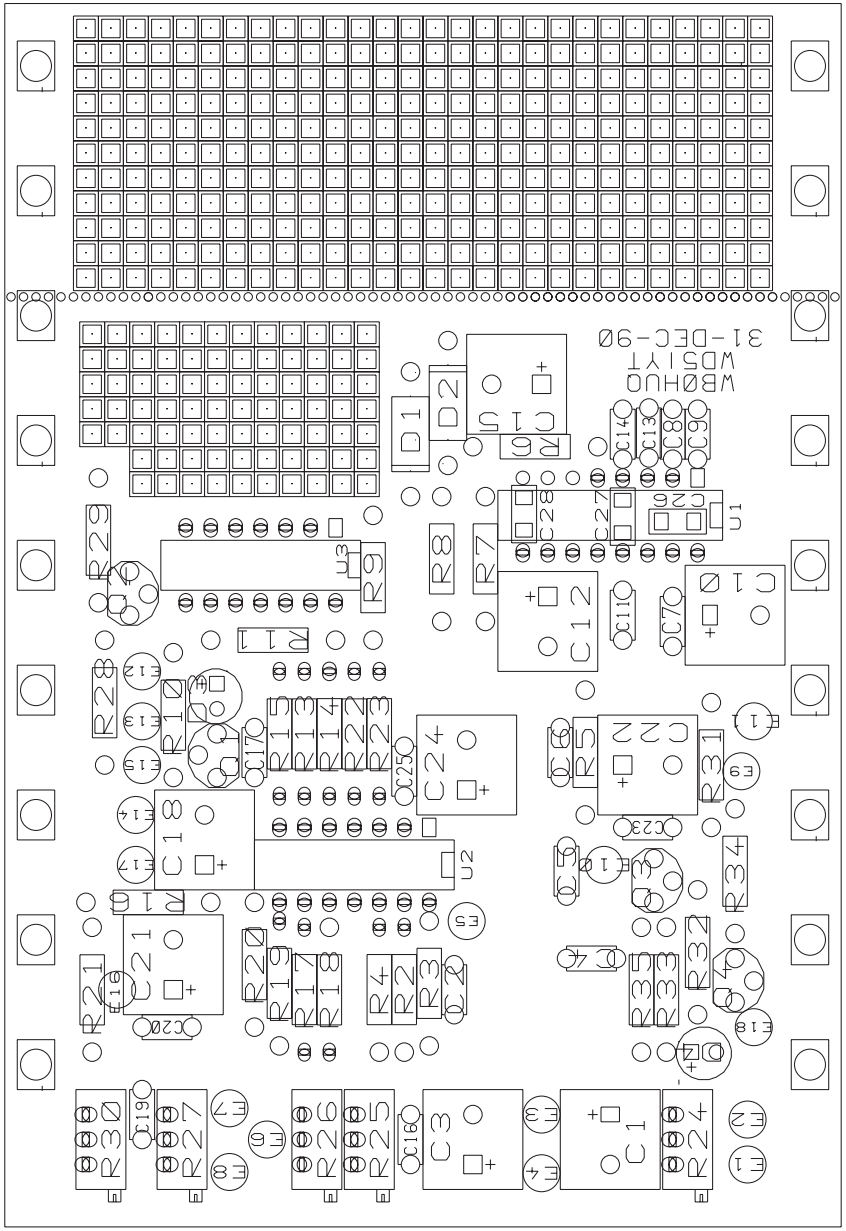

Component Side

000-1016-0001 B1 PC Board Layout