GamePlan Multi MPU

Replacement MPU

(Replaces MPU-1 and MPU-2 boards)

Board designed by Jeremy Fleitz

https://www.epinball.com/

https://github.com/jfleitz/gp-mpu

Assembly documentation By Robert L. Doerr (RobotWorkshop)

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Manual Revision V1.3

NOTE: This new replacement MPU has been tested extensively in several different GamePlan games with excellent results. Although every effort has been made to ensure the compatibility with the widest range of GamePlan games (and the accuracy of the documentation) there are no guarantees expressed or implied that it will work under all circumstances.

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(D60 optional)

INTRODUCTION

GamePlan made some excellent pinball machines. Both in cocktail format like Star Trip and regular full size traditional machines like the popular Sharpshooter. Unfortunately they suffer the same fate as many other machines. GamePlan used an on board Ni-Cad battery pack directly on the MPU board to retain scores and audit settings. That battery is prone to leak and has ruined many, many boards. As a result a lot of great machines were set aside and even discarded or stripped for parts.

There have been limited runs of MPU boards compatible to the original but the availability is spotty at best and limits the ability to revive many games. Thankfully there is now a new option! You can build your own replacement MPU to help keep these games alive. Jeremy did a fantastic job on the board layout and these instructions were written to assist you and help successfully assemble this open source option.

While the default setup of this board is to use NVRAM it is also possible to use a 6264 SRAM instead. This uses a coin cell battery or an off board battery pack. If you want to use this option then you need a few optional components. A coin cell battery holder, a 1N5817 diode (instead of jumper) for D60, and a 1N4004 diode for D59. Any 6264 SRAM used should be the LP or other low power part to conserve the battery. NOTE: These diode locations supersede the ones marked on the board.

The game ROM images used are from the original release of the title and have not been modified. Modification to the game ROM itself is not permitted when using this image.

Filename: gp-mpu.bin Rom Type: 27c020 / 27c2001 (256kbx8) Checksum: 0xED90

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This new MPU board will support all the GamePlan games by setting which game you want to use it in with a 4 position DIP switch (SW1) on the MPU. The 4 individual switches on SW1 set which bank (or portion of code) should be used within the large EPROM. This makes it easy to move to a different game just by altering these switches instead of swapping ROM chips around. The game selection settings are:

1234 – Switch #

0000 – SharpShooter, SharpShooter 2, Coney Island, Lizard
0001 – Super Nova
0010 – Global Warfare
0011 – Attila the Hun
0100 – Agents 777
0110 – Captain Hook
0111 – Andromeda
1000 – Cyclopes
1001 – Cocktail 110: Foxy Lady, Real, Rio, Black Velvet, Camel Lights, Chuck-A-Luck
1010 – Cocktail 120: Star Trip, Family Fun!
1100 – Cocktail 140: Vegas
1110 – Cocktail 830: Lady SharpShooter
1111 – *Reserved*

NOTE: If your machine isn't working properly then it is best to do some diagnostic testing FIRST. While the MPU in your current machine may have a fault, there are often multiple issues. Just popping in a new board isn't necessarily a magic bullet to make it all start working. If it had battery damage then it may have damaged the connectors on the wiring harness too. That will need to be addressed as well as any power issues before proceeding.

If the Multi MPU is already assembled, please proceed to the testing and operation section.

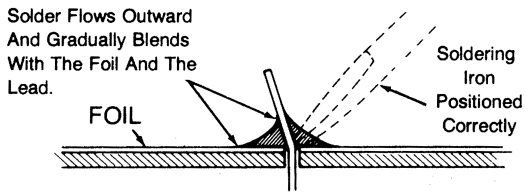
CIRCUIT ASSEMBLY

(Kit version only)

This kit should be built using standard construction methods. The following items are required to build the kit: diagonal cutter, needle nose pliers, soldering iron (pencil type) with fine tip, 60/40 Rosin core solder, and some patience. It helps to have a lead forming tool for the resistors. (There are some available to download and print from Thingiverse.com) Follow the instructions carefully and read the entire step before performing each operation. To successfully assemble this kit you must have good soldering skills. A good solder connection will form the electrical connection between two parts, such as a component lead and a circuit board foil. Care also needs to be taken to ensure that there are no solder bridges causing shorts. A bad solder connection could prevent an otherwise well-assembled kit from operating properly.

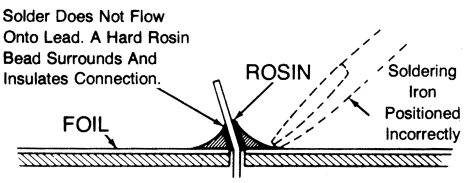
During assembly make sure you keep the soldering iron tip clean. Wipe it often on a wet sponge or cloth; then apply solder to the tip to give the entire tip a wet look. This process is called tinning, and it will protect the tip and enable you to make good connections. When the solder tends to "ball" or does not stick to the tip, the tip needs to be cleaned and retinned. The following illustrations show a good solder connection as well as a couple examples of ones that are poor and need to be redone.

A GOOD SOLDER CONNECTION

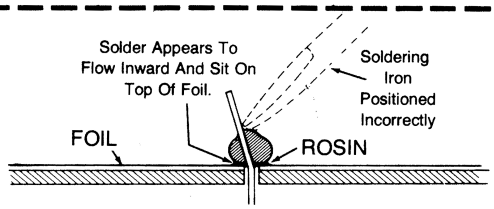


When you heat the lead and the circuit board foil at the same time, the solder will flow evenly onto the lead and the foil. The solder will make a good electrical connection between the lead and the foil.

POOR SOLDER CONNECTIONS



When the lead is not heated sufficiently, the solder will not flow onto the lead as shown above. To correct, reheat the connection and, if necessary, apply a small amount of additional solder to obtain a good connection.



When the foil is not heated sufficiently the solder will blob on the circuit board as shown above. To correct, reheat the connection and, if necessary, apply a small amount of additional solder to obtain a good connection.

The component side of the board has the silk screen with all the writing. All of the components will be mounted on the component side of the board. After installing each component at the specified location solder it in place before proceeding to the next. When installing DIP socket it works best if each of the two opposing corners is soldered first. Then gently press on the center of the socket while warming the solder on those corner pins with the soldering iron to make sure the socket is properly seated. Finally solder the rest of the leads on the socket. This method gives the board a much cleaner look than if the leads on the sockets have been folded over to hold it in place before soldering.

***NOTE**:* While this board could be assembled in just about any order it helps to install some of the smaller components first like resistors, capacitors, and diodes. Then parts like the DIP sockets, switches, LED's, etc. That is how the following instructions are structured. You'll have to reference the silkscreen on the PCB when installing each part. Parts will be installed based on their value with like parts being installed as a group. You can check each group off as you go. Now let's get started!

- ❑ Install the (7) **100 ohm ¼ watt** resistors at locations R16, R17, R18, R19, R20, R21, and R22. These can be inserted in either direction since polarity does not matter. But it is a good convention to orient all the strips in a unified direction for a cleaner look. *R16 is near U12.*

- ❑ Install the **220 ohm ¼ watt** resistor at location R82. This can be inserted in either direction since polarity does not matter.

- ❑ Install the **270 ohm ¼ watt** resistor at location R77. This can be inserted in either direction since polarity does not matter.

- ❑ Install the (2) **330 ohm ¼ watt** resistors at locations R24, and R25. These can be inserted in either direction since polarity does not matter

- ❑ Install the **470 ohm ¼ watt** resistor at location R52. This can be inserted in either direction since polarity does not matter.

- ❑ Install the (13) **1K ohm ¼ watt** resistors at locations R2, R3, R4, R5, R9, R11, R12, R13, R14, R15, R27, R43, and R81. These can be inserted in either direction since polarity does not matter. *R43 is near U16.*

- ❑ Install the (12) **1.5K ohm ¼ watt** resistors at locations R6, R7, R8, R10, R23, R36, R37, R38, R39, R40, R41, and R42. These can be inserted in either direction since polarity does not matter.

- ❑ Install the (12) **2.2K ohm ¼ watt** resistors at locations R28, R29, R32, R44, R45, R46, R47, R48, R49, R50, R51, and R80. These can be inserted in either direction since polarity does not matter.

- ❑ Install the (9) **3.3K ohm ¼ watt** resistors at locations R31, R54, R56, R58, R60, R62, R64, R66, and R68. These can be inserted in either direction since polarity does not matter.

- ❑ Install the (12) **10K ohm ¼ watt** resistors at locations R1, R26, R34, R35, R83, R84, R85, R86, R87, R88, R89, and R90. These can be inserted in either direction since polarity does not matter.

- ❑ Install the (11) **100K ohm ¼ watt** resistors at locations R30, R53, R55, R57, R59, R61, R63, R65, R67, R78, and R79. These can be inserted in either direction since polarity does not matter.

- ❑ Install the (9) **220K ohm ¼ watt** resistors at locations R33, R69, R70, R71, R72, R73, R74, R75, and R76. These can be inserted in either direction since polarity does not matter.

- ❑ Install the **.01uf (103) capacitor** at location C1. This can be inserted in either direction since polarity does not matter.

- ❑ Install the (18) **.1uf (104) capacitors** at locations C3, C6, C7, C8, C9, C10, C11, C12, C13, C14, C15, C16, C17, C18, C19, C20, C21, and C22. These can be inserted in either direction since polarity does not matter.

- ❑ Install the **.001uf (102) capacitor** at location C5. This can be inserted in either direction since polarity does not matter.

- ❑ Install the **220pf (221) capacitor** at location C2. This can be inserted in either direction since polarity does not matter.

- ❑ Install the **22uf electrolytic capacitor** at location C4. ***Polarity matters!*** Pay close attention when installing and make sure the polarity matches the silkscreen on the board. Most of the caps will have a stripe to identify the negative lead.

- ❑ Install the **.22uh inductor** at location L1. This can be inserted in either direction since polarity does not matter.

- ❑ Install the (6) **1N4004 diodes (or 1N4005, 1N4006, or 1N4007)** at locations D1, D3, D5, D7, D9, and D11. ***Polarity matters!*** Install the end with the band in the pad with the square hole. These should match the outline on the board.

- ❑ Install the (48) **1N4148 diodes** at locations D2, D4, D6, D8, D10, D12, D13, D14, D15, D16, D17, D18, D19, D20, D21, D22, D23, D24, D25, D26, D27, D28, D29, D30, D31, D32, D33, D34, D35, D36, D37, D38, D39, D40, D41, D42, D43, D44, D45, D46, D47, D48, D49, D50, D51, D53, D54, and D56. ***Polarity matters!*** Install the end with the band in the pad with the square hole.

- ❑ Install the **RED LED** at location D52. ***Polarity matters!*** Make sure you installed the shorter lead in the pad with the square hole.

- ❑ Install the (3) **GREEN LED's** at locations D55, D57, and D58. ***Polarity matters!*** Make sure you installed the shorter lead in the pad with the square hole.

- ❑ Install the **8-pin socket** at location U15. The notch should match the outline on the silkscreen.

- ❑ Install the (9) 14**-pin sockets** at locations U3, U4, U5, U9, U12, U16, U18, U19, and U20. The notch should match the outline on the silkscreen.

- ❑ Install the (3) 16**-pin sockets** at locations U10, U11, and U17. The notch should match the outline on the silkscreen.

- ❑ Install the (2) 20**-pin sockets** at locations U13 and U14. The notch should match the outline on the silkscreen.

- ❑ Install the (2) 28**-pin sockets** at locations U1 and U7. The notch should match the outline on the silkscreen.

- ❑ Install the **32-pin socket** at location U6. The notch should match the outline on the silkscreen.

- ❑ Install the (2) 40**-pin sockets** at locations U2 and U8. The notch should match the outline on the silkscreen. U8 does not face the same direction as the smaller DIP IC's on the board.

- ❑ Install the (4) **9-pin connectors** at locations J2, J4, J6, and J7. Make sure the connector is level with the board. After connector is soldered you can use flush cutters to cut the key pin.

- ❑ Install the (2) **15-pin connectors** at locations J1 and J5. Make sure the connector is level with the board. After connector is soldered you can use flush cutters to cut the key pin.

- ❑ Install the **4-position DIP switch** at SW1. Pin 1 goes in the square hole. It is best to solder one pin first to check alignment. If adjustments are needed just warm the solder on that one pin and line up the switch. Once lined up solder the remaining leads.

- ❑ Install the (4) **8-position DIP switches** at SW2, SW3, SW4, and SW5. Pin 1 goes in the square hole.
- ❑ Install the **Momentary switch** at SW6. Switch body should be flush with the board before soldering.
- ❑ Install the **2N3904 transistor** at Q1. The body of the transistor should match the silkscreen. The leads on this part are very close together so triple check to ensure no solder bridges after soldering!
- ❑ Install the **2.4576 Mhz crystal** at Y1. The body of the crystal should lay flat against the board. Use a small square to double face tape or a bit of glue to ensure the body of the crystal doesn't move.
- ❑ **Only for NVRAM:** install a scrap lead from a resistor at location D59 instead of a diode and solder.
- ❑ *OPTIONAL:* De-flux and clean the board. This step is not required but when properly cleaned the board's appearance is better and it is easier to spot cold solder joints and solder bridges. Depending upon the type of flux used, this can be done economically using common rubbing alcohol and an old toothbrush.

Now it is time to install all of the IC's in their sockets. When inserting be careful not to have a lead fold under the IC or hang out the side. Make sure the notch matches the orientation on the silk screen.

- ❑ Install the **Z80 CTC** chip in socket U1.
- ❑ Install the **Z80 CPU** chip in socket U2.
- ❑ Install the **74LS04** chip in socket U3.
- ❑ Install the **74LS32** chip in socket U4.
- ❑ Install the **74LS00** chips in sockets U5 and U12.
- ❑ Install the **27C020 EPROM** chip in socket U6. Make sure it has been programmed with the combo binary and has a label to cover the window! (EPROMS included in kit should be all set)
- ❑ Install the **FM16W08-SG NVRAM** chip or a **6264 SRAM** chip in socket U7.
- ❑ Install the **8255** chip in socket U8. This chip does not face the same direction as the smaller DIP IC's on the board.
- ❑ Install the **7417** chip in socket U9.
- ❑ Install the (3) **74LS138** chips in sockets U10, U11, and U17.
- ❑ Install the (2) **74LS377** chips in sockets U13 and U14.
- ❑ Install the **MIC1232** Reset chip in socket U15.
- ❑ Install the (3) **LM399** chips in sockets U16, U19, and U20.
- ❑ Install the **7416** chip in socket U18.

This concludes the Assembly procedures for the GamePlan Multi MPU. Congratulations! Before proceeding, look over the board and verify the correct location and orientation of all parts and soldering.

TESTING and OPERATION

It is advised to test your power supply in your game prior to plugging in your board. This can be accomplished with the following steps:

1. Remove the MPU board if any is installed in the game.
2. Locate **J1** on the MPU board (it is the 15-pin connector opposite side of the large edge display
3. connectors)
4. Set your meter to Volts DC
5. Use either some small wire or left over resistor leads and twist them on the end of your meter probes. This will allow you to insert the wire into the connector.
6. Pin 6 is the “Key” of the connector and has no wire to it. In fact, it should have a small little block on the female side covering up the hole.
7. Insert your black probe lead into Pin 15.
8. Turn the game on.
9. Carefully, insert the red probe into Pin 13. This should read close to 12 volts
10. Carefully, insert the red probe into Pin 12. This should read close to 5 volts
11. Carefully, insert the red probe into Pin 3. This should read close to 24 volts
12. If all voltages are ok, then you are ready to test the board!

Now that you’ve confirmed the voltages are safe to use from the pinball machine you can test the new GamePlan Multi MPU board to ensure it is booting before connecting everything else.

1. Turn the game off.
2. Set the 4-position DIP Switches on **SW1** to the game that you want to run.
3. Optional: Set the bank of four 8-position DIP switches to the game specific settings. (Refer to the original manual for those settings)
4. Mount the board in the game.
5. Only plug in connector **J1**. No other connectors should be plugged into the board.
6. Now turn the game on and watch the LEDs
7. You should have all 3 lower LEDs on, indicating power is good.
8. You will see the diagnostic LED flash 6 times. If you don’t, you need to check your work. It is recommended to first double check to make sure all pins are soldered and there are no solder joints bridged. Check the orientation of each IC and ensure the EPROM has been programmed.
9. If you see 6 flashes, you are good to go! Turn the game off and plug in the rest of the connectors.

Once everything is plugged in and powered up you will want to run through the procedure to clear each of the settings that are normally saved in NVRAM (or battery backed 6264 SRAM). You should only need to do this the first time you setup the board in the game or when moving the board and configuring it for a different title.

CIRCUIT DESCRIPTION

The circuit for this replacement MPU has a few design differences to use some newer parts that are easier to source. It also incorporates some enhancements to allow it to run in any GamePan game just by setting some DIP switches. Some of the enhancements are:

- Use easy to find components as much as possible
  - Use two 74LS377, which is 8bit vs two 74LS379 since they are easier to find
  - Use two 74LS138 vs one 74154
- Use a Power On Reset w/Watchdog to replace the reset circuitry
- Use NVRAM to eliminate any need of a battery
- Have all game roms selectable by a dip switch bank
- Provide indicators for the different voltage rails
- Keep the same footprint as the existing MPU-2 board
- Use through hole to make it easier for soldering

The revised GamePlan mpu follows the same basic design as the original MPU board. It also borrows from the "Simple Z80 System" by Thomas Scherrer, from http://www.z80.info/ (link to schematic: http://www.z80.info/gfx/z80test.gif). Page 1 on the schematic shows the basic Z80 CPU circuitry including the CTC, Ram, and ROM. With just a single ROM and single RAM used, the address select circuitry is less complex than the original, using just a few logic gates.

RAM: This board has 8k of RAM, compared to the total of 384 bytes on the original board. While this is overkill for the GamePlan games, the 6264 compatible RAM is easy to obtain.

ROM: A 27C020 was chosen so that 16kb of space is available for each "slot" for a game. Using a 4 pin dip switch to control the top 4 address lines, the 16k "slot" can be chosen for the MPU to use. It is recommended to not change the DIP switch selection of the game while it is on.

Peripherals: The remaining parts of the schematic are closely based on the original schematic, with some minor differences. The switch matrix uses two 74ls138s, 3-to-8 decoders, to select what group of switches to read the current state. This is different from the original that used one 74154, a 4-to-16 decoder, due to the 74154 being obsolete.

The two "ports" that drive the Solenoid and Sound board (or two Solenoid boards in Global Warfare's case) use two 74LS377 vs two 74LS379. Once again this was due to the 74LS377 being more available than the later.

Voltage Indicators: 3 LEDs for the 5v, 12v and 24v rails that are on the board have been added. This allows for quick diagnosis if there is a power supply issue. Since the 12v supply powers the 5v regulator, both LEDs will be off when the 12v power is bad (such as the fuse being blown).

A couple resistor values were changed to set the threshold for the comparators in the switch matrix. The 6.8K ohm pull-up is now 470 ohm and the 10K pull-down is now 1K. These changes relate to the latest release of the MPU-2 board used in CYCLOPES which should allow this board to work in all GamePlan machines.

SCHEMATIC DIAGRAM

You can find all the design files online at: https://github.com/jfleitz/gp-mpu

The schematic for the board can be found here:

https://github.com/jfleitz/gp-mpu/blob/main/printouts/gp-mpu.pdf

REPLACEMENT PARTS LIST

Components

Quantity	Description	Location
1	0.01uf	C1
1	220pf	C2
18	0.1uf	C3, C6, C7, C8, C9, C10, C11, C12, C13, C14, C15, C16, C17, C18, C19, C20, C21, C22
1	22uf	C4
1	0.001uf	C5
6	1N4004	D1, D3, D5, D7, D9, D11 (D59 optional)
1	1N5817 (optional for 6264 SRAM) or wire for NVRAM	D60 (install here instead of D59 on board)
48 (1 extra needed for 6264 SRAM)	1N4148 (	D2, D4, D6, D8, D10, D12, D13, D14, D15, D16, D17, D18, D19, D20, D21, D22, D23, D24, D25, D26, D27, D28, D29, D30, D31, D32, D33, D34, D35, D36, D37, D38, D39, D40, D41, D42, D43, D44, D45, D46, D47, D48, D49, D50, D51, D53, D54, D56
1	T1 LED - RED	D52
3	T1 LED - GREEN	D55, D57, D58
4	9-pin .100” header	J2, J4, J6, J7
2	15-pin .100” header	J1, J5
1	0.22uh	L1
1	2N3904	Q1
12	10K ohm 1/4W	R1, R26, R34, R35, R83, R84, R85, R86, R87, R88, R89, R90
13	1K ohm 1/4W	R2, R3, R4, R5, R9, R11, R12, R13, R14, R15, R27, R43, R81
12	1.5K ohm 1/4W	R6, R7, R8, R10, R23, R36, R37, R38, R39, R40, R41, R42
7	100 ohm 1/4W	R16, R17, R18, R19, R20, R21, R22
2	330 ohm 1/4W	R24, R25
12	2.2K ohm 1/4W	R28, R29, R32, R44, R45, R46, R47, R48, R49, R50, R51, R80
11	100K ohm 1/4W	R30, R53, R55, R57, R59, R61, R63, R65, R67, R78, R79
9	3.3K ohm 1/4W	R31, R54, R56, R58, R60, R62, R64, R66, R68
9	220K ohm 1/4W	R33, R69, R70, R71, R72, R73, R74, R75, R76
1	470 ohm 1/4W	R52
1	270 ohm 1/4W	R77
1	220 ohm 1/4W	R82
1	4 Pos Dip Switch	SW1
4	8 Pos Dip Switch	SW2,SW3,SW4,SW5,SW6
1	Reset (Momentary switch)	SW6
1	Z80-CTC	U1
1	Z80CPU	U2
1	74LS04	U3
1	74LS32	U4
2	74LS00	U5, U12
1	27C020 (need to program with Combo binary)	U6
1	FM16W08-SG	U7
1	8255	U8
1	7417	U9
3	74LS138	U10, U11, U17
2	74LS377	U13, U14
1	MIC1232	U15
3	LM339	U16, U19, U20
1	7416	U18
1	2.4576mhz HC-49 case	Y1
1	8-pin DIP socket	U15
9	14-pin DIP sockets	U3, U4, U5, U9, U12, U16, U18, U19, U20
3	16-pin DIP sockets	U10, U11, U17
2	20-pin DIP sockets	U13, U14
2	28-pin DIP sockets	U1, U7
1	32-pin DIP socket	U6
2	40-pin DIP sockets	U2, U8

Revision History

Version 1.0
- Leverages NVRAM to eliminate the onboard battery
- Has all ROMs from the produced GamePlan machines in one location, that can be chosen by 4 dip switches
- Has onboard LED indicators to show that the different power rails are working
- Less components, and components have been chosen that are still produced

Version 1.2
- Mounting holes enlarged to 5/32
- Label for key on J7 moved to pin 3

Version 1.3
- Add more Vias to power rails for redundancy
- Keep Vias exposed for troubleshooting
- Add Battery option for 6264 RAM vs NVRAM use
- Add Ext battery connector for off-board battery option

NOTE: If using NVRAM, install a wire jumper at D59

Version 1.4
- All vias enlarge to support wirewrap 28ga if necessary
- Vias are not tented

SPECIAL THANKS

A note of thanks to Jeremy Fleitz for sharing his board design! This will help save a lot of GamePlan machines.

Special thanks to Roger Sharpe and Lee Goldboss for supporting this effort!

All the users who have responded with their feedback to improve the documentation.