Micro 8088 – IBM XT Compatible Processor Board

Please refer to https://github.com/skiselev/micro_8088 for more documentation including the schematic and design files.

Introduction

The Micro 8088 is an ISA form factor card that implements the functionality of an IBM PC/XT compatible computer. To make a complete computer system, the Micro 8088 card should be plugged into an ISA backplane, such as the ISA 8-bit Backplane [https://github.com/skiselev/isa8_backplane], together with other cards, like a CGA, EGA, or VGA controller, and a mass storage controller: a floppy disk controller, an XT-CF-Lite CompactFlash interface, or an XT-IDE controller. Other ISA cards can be added if desired. Note that the Micro 8088 only supports an 8-bit data bus. Some, but not all 16-bit ISA cards work in an 8-bit data bus. Most AT IDE/ATA controllers require a 16-bit ISA bus and will not work in an 8-bit ISA slot.

The Micro 8088 uses through-hole components only, and is relatively easy to build. Yet there are quite a few components to solder, so take your time and enjoy the process!

Tools and Materials

Gather necessary tools and materials before assembling this project. Here is the recommended list:

- Well-lit table or work bench.
- Soldering iron with a fine tip. Temperature controlled soldering station is recommended.
- Needle nose pliers for forming components' leads.
- Small side cutters for trimming leads after the components have been soldered.
- A pair of pliers or tweezers for holding small parts.
- A PLCC IC extraction tool (optional).
- Small flat head and Philips screwdrivers.
- Rosin core solder wire suitable for electronics. For example Sn63/Pb37, Sn60/Pb40, or a lead-free solder such as Sn96.5/Ag3.0/Cu0.5 (SAC305).
- Solder wick for removing excess solder.
- 99% Isopropyl Alcohol for removing the excess flux after soldering.
- Lint free wipes, used toothbrush, and cotton swabs for cleaning the PCB before and after soldering.
- A multimeter with frequency measurement, an oscilloscope, or a logic analyzer can be useful for troubleshooting.
- For the PCB and chipset kit only:
    - Universal programmer capable of programming SST39F010A Flash ROM ICs, PIC12F629 Microcontrollers, and ATF16V8B SPLDs. For example, MiniPro TL866CS or MiniPro TL866A.
- For manufacturing metal ISA bracket:
    - Electric drill and drill bits for drilling holes in the ISA bracket.
    - Small semi-round file for smoothing holes in the ISA bracket.

Components

- The complete kit contains all the components needed to build the Micro 8088 card.
- Please refer to the **Bill of Materials** table below for the components needed to build the PCB and chipset kit.

Bill of Materials

Component type	Reference	Description	Quantity	Possible sources and notes
PCB		Micro 8080 PCB - Version 1.4	1	Included in the kit
Integrated Circuit	U1	Intel 8088, 80C88, or NEC V20 CPU	1	eBay, Mouser (expensive) - 968-CP80C88-2Z
Integrated Circuit	U2	Intel 8087 FPU	1	Optional, eBay
Integrated Circuit	U3	Proton PT8010AF	1	Included in the kit

Integrated Circuit	U4	SST39SF010A Flash ROM, DIP-32	1	Mouser 804-39SF010A7CPHE
Integrated Circuit	U5, U6	AS6C4008 SRAM, DIP-32 package	2	Mouser 913-AS6C4008-55PCN
Integrated Circuit	U7 - U9	74F573 Octal D-Type Latch	3	Mouser 595-SN74F573N
Integrated Circuit	U10, U11	74F245 Octal Bus Transceiver	2	Mouser 595-SN74F245N
Integrated Circuit	U12, U13	74F244 Octal Buffer	2	Mouser 595-SN74F244N
Integrated Circuit	U14	74F00 Quad 2-Input NAND Gate	1	Mouser 595-SN74F00. **Important note: install either U14 or U16, not both together**
Integrated Circuit	U15	PIC12F629 Microcontroller	1	Mouser PIC12F629-I-P
Integrated Circuit	U16	ATF16V8B SPLD	1	Mouser 556-AF16V8B15PU. **Important note: install either U14 or U16, not both together**
IC Socket	U1, U2	DIP-40, 600 mil socket	2	Mouser 649-DILB40P223TLF
IC Socket	U3	PLCC-84 through hole socket	1	Mouser 517-8484-11B1-RK-TP
IC Socket	U4-U6	DIP-32, 600 mil socket	3	Mouser 649-DILB32P223TLF
IC Socket	U7-U13, U16	DIP-20, 300 mil socket	8	Mouser 649-DILB20P-223TLF
IC Socket	U14	DIP-14, 300 mil socket	1	Mouser 649-DILB14P-223TLF
IC Socket	U15	DIP-8, 300 mil socket	1	Mouser 649-DILB8P223TLF
Diode	D1	1N4148	1	Mouser 512-1N4148
LED	D2	3 mm, green LED indicator	1	Mouser LTL-4231NHBP
Transistor	Q1	PN2222A, 2.54mm lead spacing	1	Mouser 512-PN2222ATA
Crystal	X1	28.63636 MHz, 18 pF, HC-49/S	1	Included in the kit
Speaker	SP1	12 mm speaker	1	Mouser 665-AT-1224TWTR
Tactile Button	SW1	6 mm tactile button, right angle	1	Mouser 653-B3F-3152
DIP Switch	SW2	3 positions	1	Mouser 774-2063
DIP Switch	SW3	5 positions	1	Mouser 774-2065
Connector	P1	6 pin Mini DIN, purple	1	Mouser 806-KMDGX-6S-BS
Pin Header	P2, JP3-JP4	4 pin header, 2.54 mm pitch	2	Mouser 649-68002-104HLF
Pin Header	P3, JP1-JP2	2 pin header, 2.54 mm pitch	3	Mouser 649-68002-102HLF
Capacitor	C1 - C17	0.1 uF, MLCC, 5 mm lead spacing	17	Mouser 810-FG28X7R1H104KNT6
Capacitor	C18 - C20	10 uF, MLCC, 5 mm lead spacing	3	Mouser 810-FG28X5R1E106MR06
Trimmer Capacitor	C21	GKG30015, 6.5-30 pF, 5 mm pitch	1	Included in the kit
Capacitor	C22	47 pF, MLCC, 5 mm lead spacing	1	Mouser 810-FG28C0G1H470JNT6
Capacitor	C23	0.01 uF, MLCC, 5 mm lead spacing	1	Mouser 810-FG28X7R1H103KNT6
Resistor Array	RR1	4.7 k, bussed, 10 pin SIP	1	Mouser 652-4610X-1LF-4.7K
Resistor Array	RR2	10 k, bussed, 10 pin SIP	1	Mouser 652-4610X-1LF-10K
Resistor Array	RR3, RR4	4.7 k, bussed, 6 pin SIP	2	Mouser 652-4606X-1LF-4.7K
Resistor Array	RR5	10 k, bussed, 6 pin SIP	1	Mouser 652-4606X-1LF-10K
Resistor	R1	33 ohm, through hole	1	Mouser 603-MFR-25FBF52-33R
Resistor	R2, R3	47 ohm, through hole	2	Mouser 603-MFR-25FBF52-47R
Resistor	R4, R5	470 ohm, through hole	2	Mouser 603-MFR-25FBF52-470R
Resistor	R6	1 kohm, through hole	1	Mouser 603-MFR-25FBF52-1K
Resistor	R7	10 kohm, through hole	1	Mouser 603-MFR-25FBF52-10K
Resistor	R8	1 Mohm, through hole	1	Mouser 603-MFR-25FBF52-1M
Fuse	F1	1.1A polyfuse, 5.08 mm lead pitch	1	Mouser 650-RUSBF110-2
ISA Bracket		Keystone Electronics 9202, drill holes for components as needed	1	3D printed bracket included Metal bracket: Mouser 534-9202
Screw		4-40 x 1/4" Screw	2	Included in the kit

Possible Components Replacement (PCB and Chipset Kit Only)

- The recommended logic family is the Fast TTL 74F-series.
  - Possible replacement is the Advanced Low-Power Schottky 74ALS-series.
  - 74LS, 74HCT, 74AHCT, 74ACT series logic might work as well, but have not been tested.
- The recommended CPU is 10 MHz 8088, for example AMD P8088-1, or Siemens SAB 8088-1-P.
  - Possible replacements are 10 MHz or higher NEC V20 (µPD70108C-10) or NEC V20HL (µPD70108HCZ-10, µPD70108HCZ-16).
  - 8 MHz 8088-2, 80C88-2, and NEC V20 (µPD70108C-8) parts might work as well.
- The recommended SPLD is Atmel ATF16V8B. It can be replaced with Lattice GAL16V8D or similar.
  - Make sure that your programmer supports the SPLD type you're planning to use.
  - Note that SPLD part is optional, and a 74F00 logic IC can be used instead.
- The recommended Flash ROM part is Microchip SST39SF010A.
  - Other 128 KiB, 5V-only Flash ROM ICs can be used, for example Atmel AT29C010, Winbond W29EE011, Greenliant GLS29EE010, AMD Am29F010B.
- The recommended SRAM part is Alliance Memory AS6C4008-55PCN.
  - Other 512 KiB, TTL compatible SRAM ICs should work, for example Hitachi HM628512, BSI BS62LV4006PC.
- Electrolytic or tantalum capacitors can be used for C18-C20 10 uF. Make sure to observe the polarity in this case.

Assembly Steps

1. Inspect the PCB for obvious defects, such as deep scratches or short-circuits between traces.
2. Clean the PCB with an alcohol wipe.
3. Solder the components, going from lower profile components to higher profile ones:
   a. Form the leads and solder the D1 diode using needle nose pliers. Pay attention to the diode's polarity. The black band on the diode should match the band on the silkscreen.
   b. Solder the R1-R8 resistors. The resistors don't have polarity and can be soldered either way. Using your fingers gently bend the resistors' leads 90° near the package so that they can be inserted into the PCB. It is not recommended to use metal tools for bending leads, as they might damage the resistors.
   c. Make a U-shaped wire jumper from one of the trimmed resistor leads and install it at JP2. This configures the chipset to work with 28.62626 MHz crystal supplied with the kit.
   d. Solder the X1 crystal. Place the provided crystal insulator between the crystal and the PCB.
   e. Solder the C1-C23 capacitors. Pay attention to the capacitors polarity if using polarized capacitors.
   f. Solder the RR1-RR5 resistor arrays. Pay attention to the orientation - pin number 1 is usually marked with a dot on the resistor array. Square pads on the PCB are used to mark the first pin.
   g. Solder all the DIP sockets - U1, U2, and U4 - U16. Make sure that the socket is oriented correctly – the notch matches the drawing on the PCB silk screen. Also make sure that the socket is flat on the PCB. It is a good idea to solder two opposite pins first, double check the orientation and that the socket sits flat on the PCB, and then solder the rest of the pins.
   h. Solder the PLCC socket for U3. Pay close attention to the orientation of this socket.
   i. Solder the DIP switches SW2 and SW3.
   j. Solder the LED D2. Pay attention to the LED polarity. If using a regular 3 mm LED you might want to bend its leads at the right angle, so that it points towards, and sticks through the ISA bracket.
   k. Solder the Q1 transistor.
   l. Solder the P2 and JP1 headers. If ***not*** using the U16 SPLD, solder the JP3 - JP4 header and place jumpers across JP3 and JP4 respectively, or solder wire jumpers in JP3 and JP4 positions.
   m. Solder the SW1 tactile button.
   n. Solder the F1 polyfuse.
   o. Solder the P1 Mini DIN connector.
   p. Solder the SP1 speaker. Pay attention to the polarity.

4. Carefully inspect all the solder joints. Re-solder if needed. Optionally use a multimeter to check the board for short-circuits, and for the power supply signals connectivity.
5. Clean the board using cotton swaps, wipes, and the toothbrush soaked in alcohol.
6. *PCB and Chipset Kit only*: Program the firmware.
    a. Program the Flash ROM with the BIOS image [https://github.com/skiselev/micro_8088].
    b. Program the PIC12F629 microcontroller with the AT2XT Firmware [https://forum.vcfed.org/index.php?threads/at2xt-keyboard-converter.26861/].
    c. If using U16 SPLD, program it with this fuse map [https://github.com/skiselev/micro_8088/blob/master/SPLD/micro_8088_prod.jed].
7. Carefully install ICs into the sockets. Use a hard non-static surface to bend the pins of ICs in DIP packages as needed. Double check the orientation of the ICs. Make sure that all ICs pins are inserted into the sockets, and not bent. Note that the chipset IC Proton PT8010AF is installed upside down compared to other ICs.
8. Inspect the completed board once again.
9. Install the configuration jumpers, and set the DIP switches as needed. Refer to the **Jumpers, Connectors, and Switches** section below.
10. If desired, manufacture metal ISA bracket. Drill holes in a Keystone Electronics 9202 bracket for the keyboard connector, the Power LED, and the Reset switch. Finish the holes with a fine file.
11. Attach the ISA bracket to the board using two 4-40 x 1/4" screws.
12. Install the Micro 8088 board and other ISA cards in the ISA backplane. Connect the power supply.
13. Turn on the power, test the board, install your favorite software, and enjoy!

Jumpers, Connectors, and Switches

P1 - PS/2 Keyboard

Pin	Description
1	Keyboard data
2	Unused
3	GND
4	+5V
5	Keyboard clock
6	Unused

P2 - Speaker

Pin	Description	
1	Speaker output	
2	Internal Speaker input*	To enable internal speaker place a jumper across pins 1-2
3	Unused	
4	+5V	

P3 - Reset Switch

Pin	Description
1	Reset input
2	Ground

JP1 - Select Flash ROM area mapped to 0xF0000-0xFFFFF

Position	Description
open (default)	Map lower 64 KiB of the Flash ROM to 0xF0000-0xFFFFF
closed	Map upper 64 KiB of the Flash ROM to 0xF0000-0xFFFFF

JP2 - Select X1 Crystal Frequency

Position	Description	Supported CPU Clock Frequencies
open	Use 14.31818 MHz crystal	4.77 MHz, 7.16 MHz
closed (default)	Use 28.63636 MHz crystal (supplied with the kit)	4.77 MHz, 7.16 MHz, 9.55 MHz

JP3 - RAM Chip Select Source

Position	Description
open (default)	Use the SPLD (U16)
closed	Use the chipset

Note: The chipset only generates RAM chip select for the base RAM (lower 640 KiB). It does not generate RAM chip select for UMBs, and therefore the U16 SPLD is required to implement UMBs.

JP4 - Flash ROM Chip Select Source

Position	Description
open (default)	Use the SPLD (U16)
Closed	Use the chipset

Note: The chipset does not generate chip select for memory write cycles, therefore it does not support in-system BIOS upgrades. The U16 SPLD is required for in-system flash ROM write access.

SW1 - Reset Switch

Press SW1 to reset the system.

SW2 - System Configuration

Position	Description	Position	Description
SW2.1 = OFF, SW2.2 = OFF	MDA or Hercules	**SW2.3 = OFF**	Disable keyboard 0xE0 scan code pass through
SW2.1 = ON, SW2.2 = OFF	CGA, 80x25	**SW2.3 = ON**	Enable keyboard 0xE0 scan code pass through
SW2.1 = OFF, SW2.2 = ON	CGA, 40x25		
SW2.1 = ON, SW2.2 = ON	None, EGA, or VGA		

SW3 - UMB Configuration

Position	Description	Position	Description
SW3.1 = ON	Map 0xC0000-0xC7FFF to RAM	**SW3.4 = ON**	Map 0xD8000-0xDFFFF to RAM
SW3.2 = ON	Map 0xC8000-0xCFFFF to RAM	**SW3.5 = ON**	Map 0xE0000-0xEFFFF to RAM
SW3.3 = ON	Map 0xD0000-0xD7FFF to RAM		

Note: The U16 SPLD is required to implement UMBs. This switch is not used in systems without the SPLD.

Troubleshooting Tips

- Inspect your board for any soldering issues, e.g., unsoldered pins and solder bridges.
- Check the jumpers and the switches settings. Pay attention to the SW3 switch settings, and make sure that the selected UMB addresses do not conflict with BIOS extension ROMs. For example 0xC0000-0xC7FFF range is normally used by VGA BIOS, make sure that the corresponding switch is turned off when using VGA card.
- Make sure that your system is getting the power, and that power supply voltage is within 5%-10% range of the nominal voltage.
- Observe the system activity:
    - Does it produce any beeping sounds?
    - Using a multimeter with frequency measurement or an oscilloscope check for pulses on the key processor and ISA bus signals:
        - CPU signals: CLK (pin 19), AD0 (pin 16).
        - ISA bus signals: A0 (pin 62), /MEMR (pin 12), /MEMW (pin 11), /IOR (pin 14), /IOW (pin 13).
    - Using an ISA POST card or a backplane with a POST display, check if system outputs any POST codes. If so, is there any particular code it is getting stuck on? Refer to the Micro 8088 BIOS **errno.inc** for the POST codes: [https://github.com/skiselev/8088_bios/blob/master/src/errno.inc]

Micro 8088 Schematic