SPECIFICATIONS

Power Ratings
Supply ........................................... 10.5 V DC
Consumption ..................................... approx. 4 W

CPU and Memory
Processor .................................. 6280 at 7.2 MHz
RAM ............................................. 8 Kbytes
VRAM ............................................ 64 Kbytes (16 bit)

Graphics
Output ......................................... composite video (NTSC) on RF channel 3 or 4
Maximum Resolution ..................... 256 x 216
Color Palette .................................. 512 colors
Colors/Card ...................................... 16

Sprites
Number/Screen .............................. 64
Colors/Sprite .................................. 16
Maximum Number/Scanline ............. 16

Stereo Audio
RF Output ...................................... L + R composite mono
Expansion Bus ............................... L + R separate, 2 channels

Accessories
TurboPad Controller, TurboChip Game Card, AC Adapter, RF Switch
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## TABLE OF CONTENTS

- Specifications ........................................... 1
- Table of Contents ..................................... 2
- Safety Precautions .................................... 3
- Design Information .................................... 4
- Disassembly/Assembly .................................. 6
- Troubleshooting ......................................... 8
- Pin Assignments ........................................ 15
- Block Diagrams ......................................... 20
- Parts List ................................................ 22
- Schematics .............................................. 26
SAFETY PRECAUTIONS

1. Before returning an instrument to the customer, always make a safety check of the entire instrument, including, but not limited to the following items:
   a. Be sure that no built-in protective devices are defective and/or have been defeated during servicing.
   (1) Protective shields are provided on this chassis to protect both the technician and the customer. Correctly replace all missing protective shields, including any removed for servicing convenience.
   (2) When reinstalling the chassis and/or other assembly in the cabinet, be sure to put back in place all protective devices, including, but not limited to, nonmetallic control knobs, insulating fishpapers, adjustment and compartment covers/shields, and isolation resistor/capacitor networks.
   Do not operate this instrument or permit it to be operated without all protective devices correctly installed and functioning.
   b. Be sure that there are no cabinet openings through which an adult or child might be able to insert their fingers and contact a hazardous voltage. Such openings include, but are not limited to, excessively wide cabinet ventilation slots, and/or an improperly fitted and/or incorrectly secured cabinet back cover.
   c. Leakage Current Hot Check - With the instrument completely reassembled, plug the AC line cord directly into a 120 V AC outlet. (Do not use an isolation transformer during this test.) Use a leakage current tester or metering system that complies with American National Standards Institute (ANSI) C101.1 Leakage Current for Appliances, and Underwriters Laboratories (UL) 1410, (50.7). With the instrument AC switch first in the on position and then in the off position, measure from a known earth ground (metal waterpipe, conduit, etc.) to all exposed metal parts of the instrument (antennas, handle bracket, metal cabinet, screw heads, metallic overlays, control shafts, etc.), especially any exposed metal parts that offer an electrical return path to the chassis. Any current measured must not exceed 0.5 millamp. Reverse the instrument power cord plug in the outlet and repeat test.

ANY MEASUREMENTS NOT WITHIN THE LIMITS SPECIFIED HEREIN INDICATE A POTENTIAL SHOCK HAZARD THAT MUST BE ELIMINATED BEFORE RETURNING THE INSTRUMENT TO THE CUSTOMER.

2. Read and comply with all caution and safety-related notes on or inside the cabinet, or on the chassis.

3. Design Alteration Warning - Do not alter or add to the mechanical or electrical design of this unit. Design alterations and additions, including, but not limited to, circuit modifications, and the addition of items such as auxiliary audio and/or video output connections might alter the safety characteristics of this unit and create a hazard to the user. Any design alterations or additions will void the manufacturers warranty and will make you, the servicer, responsible for personal injury of property damage resulting therefrom.

4. Observe original lead dress. Take extra care to assure correct lead dress in the following areas: near sharp edges, near thermally hot parts - be sure that leads and components do not touch thermally hot parts, the AC supply, high voltage, and antenna wiring. Always inspect in all areas for pinched, out-of-place, or frayed wiring. Do not change spacing between components, and between components and the printed circuit board. Check AC power cord for damage.

5. Components, parts, and/or wiring that appear to have overheated or are otherwise damaged should be replaced with components, parts, or wiring that meet original specifications. Additionally, determine the cause of overheating and/or damage, and, if necessary, take corrective action to remove any potential safety hazard.

6. SAFETY PRODUCT NOTICE - some electrical and mechanical parts have special safety-related characteristics which are often not evident from visual inspection, nor can the protection they give necessarily be obtained by replacing them with components rated for higher voltage, wattage, etc. Parts that have special safety characteristics are identified by an asterisk or an exclamation point inscribed in a triangle on the schematics and parts list. Use of a substitute replacement that does not have the same safety characteristics as the recommended replacement part might create shock, fire, and/or other hazards. Product Safety is under review continuously and new instructions are issued whenever appropriate.
DESIGN INFORMATION

General

Processor: The TurboGrafx-16 contains a heavily modified 65C02 processor running at 7.2 MHz. In addition to the standard 65C02 modifications, other extensions made to the chip's instruction set enable the CPU to run routines even faster than equivalent 65C02 routines in some cases. For example, in block moves of memory data the CPU block move instructions take a minimum of 50% fewer cycles than an equivalent 65C02 routine. These instructions also save program space.

Program RAM: This is random access (modifiable) memory contained within the base unit that is available to the program. The amount of RAM is an indication of the possible complexity of the games. With 8K of RAM, the TurboGrafx-16 is capable of very deep and complex play.

Video RAM: This is an indication of how complex the graphics can be. The TurboGrafx-16, with 64K VRAM and one ROM address space, downloads only the characters it needs into VRAM so it doesn't have copies of certain characters (like alphanumeric characters) in each bank of ROM. In addition, because the character set is in RAM, it can be modified on the fly. With more than enough VRAM in the system to provide a unique character for every location on the screen, a bit map screen can be simulated. This is essential in certain types of games like flight simulators.

The VRAM on the NEC machine is 16 bits wide. This can be easily understood with the use of an analogy. Compare the basic process of video display to a highway. One needs to get from one place (memory) to another (the display). To increase the amount of traffic (data rate) you can move from place to place, you can increase the speed (clock rate) or you can increase the number of lanes (the bus width). The TurboGrafx-16 uses both techniques with a 16 bit transfer path and a 7.2 MHz processor.

Timer: The NEC machine contains a hardware timer, providing greatly increased capabilities in such areas as sound effects.

Background

Resolution: This represents the practical maximum that can be displayed on a television set without interleaving. (Interleaving could double the vertical resolution but at the expense of noticeable flicker). The TurboGrafx-16 can be programmed to a higher resolution, approximately 320 dots across, but color distortions may be introduced, especially on the sprites. With proper color choice on certain games, this effect is minimized.

Color Palette: The TurboGrafx-16 has 512 colors. The human eye is very color oriented and a large number of colors is better received than increased resolution. As mentioned in the RESOLUTION discussion, this machine has pretty much the practical limit when it comes to resolution, a limit set by normal TV broadcasts. Why do broadcasts look superior to computer images? This is due to a large number of colors which produce a smoothing effect (anti-aliasing). While the TurboGrafx-16, with its cost constraints, cannot approach broadcast quality, it is close. The large number of colors is perhaps the biggest advantage of the TurboGrafx-16.

Card Size: All background graphics are made up of 8 pixel (dot) x 8 pixel characters.

Color/Card: The TurboGrafx-16 has 16 colors per card, making its characters complex and realistic.

Scroll Registers: The machine can move its background display (scroll) in the horizontal and vertical direction. The TurboGrafx-16 has two independent scroll registers. This makes it marginally easier to program than a machine with one scroll register (which must be written to twice), especially for games that only scroll in one direction.

Virtual Playfield: The virtual playfield is a background larger than the screen can display. The screen display is simply a window to the virtual playfield, and shows only a portion of it. This capability makes scrolling on the TurboGrafx-16 even easier to program.

Raster Interrupts: Raster interrupts tell the processor that a certain scan line has just been displayed. This information can be used to get timing information and/or to divide a screen into bands. Additional uses include changing the color palette for a certain portion of the screen, and establishing different scroll rates in different areas of the screen.
Sprites

Sprites, also called motion objects, can be visualized as characters that can be positioned on a pixel (dot) boundary over the background, thus loaning themselves to easy movement. Games involving animation and motion are easier to program on systems with sprites than on systems without sprites.

Number/Screen: The TurboGrafx-16 has 64 sprites, many more than most other home video systems. This enables the machine to play games with lots of moving objects, like R-Type, without multiplexing. (Multiplexing, a technique used in systems with a limited number of objects, uses an object for one thing on one screen and then for another thing on the next screen. It causes very noticeable flicker. An example would be Pacman on the Atari VCS.)

Color/Sprite: This is similar to the color per card noted above, 16 colors/sprite, and allows the TurboGrafx-16 to have very detailed and complex sprites.

Size: When large moving objects are required for a game, it is easiest to program if large sprites are available. Otherwise, smaller sprites must be grouped together to construct these larger objects. This increases the probability of exceeding the maximum number of sprites per scanline as mentioned below. The TurboGrafx-16, with its programmable sprite size (16x16 or 32x64 pixels), offers two approaches to sizing objects for display.

Number/Scanline: The game system draws on the display in a series of horizontal lines (scanlines). The process starts offscreen. The next line to be displayed is drawn, background first, then each sprite that is partially displayed on that scanline is drawn in sequence. There is a finite amount of time that is available to do this until the line has to be displayed. As a result, if the scanline is unfinished, some of the sprite data for that scan line may be lost. This would cause a portion of the sprite to disappear from the screen or flicker. In fact, multiplexing may have to be employed to allow more than X number of sprites on a scanline. With a 16 sprite per scanline limit, however, the possibility of multiplexing or showing visible flicker in a TurboGrafx-16 game is much less than the possibility in other popular systems.

Sound

Stereo: The TurboGrafx-16 has stereo capabilities apart from the CD ROM interface. It also has 6 programmable waveform generators. Square, sine, sawtooth, triangle and other waveforms can be easily programmed into any generator. In addition, additional noise may be mixed into generators 5 and 6.

LFO: This stands for Low Frequency Oscillator, a device used to modify sound for effects like Vibrato or Tremolo.
NOTE: The following steps are for disassembly. They will also help you reassemble the unit if you follow them backwards.

1. Turn the unit upside down and remove the 7 screws (A).

2. Lift off the bottom plastic cover. Then remove the 3 machine screws (B).

3. First, lift out the DC IN JACK (C). Then lift the entire board and shield assembly out of the top plastic cover.
4. Remove the two outside screws (D) to either side of the expansion bus cover (they hold the two shields together).

5. Desolder the 8 points (E) where the bottom shield is soldered to the board. It is easiest if you start by the controller port and work your way around the unit spot by spot.

6. Turn the board over and repeat, desoldering the 9 points (G) where the top shield is soldered to the board.

NOTE: When replacing the shields, make sure the flanges from the top shield (the shallow one) overlap the flanges from the bottom shield on either side of the expansion bus port.
TROUBLESHOOTING

REQUIRED TOOLS

Digital Multimeter
Oscilloscope (100 MHz preferred)
TurboGrafx-16 Service Manual
Solder iron
Test jig
Cabinet screwdriver
#1 Phillips screwdriver

There are two ways to troubleshoot this machine -- through software and hardware. If the unit powers up, run the test jig and troubleshoot it with the software program. If the unit doesn't power up, you must physically test the machine yourself.

GENERAL TROUBLESHOOTING

1. Check for bad solder connections. A bad solder connection will be more grey or black than silver. Also check for solder bridges, or solder connections that overlap extra pins or short parts they were not designed to connect. Resolder any bad connections. Also check for solder flux on all components.

2. Look at the connector pins for both the TurboPad and the Expansion Bus, making sure the pins are not bent, broken, and do not have open or shorted traces. Repair or replace as necessary.

3. Make sure the pins on each of the ICs are centered from the IC to the board. Also make sure none of the pins are shorted to any shield or to any other pin.

4. Measure both the input and the output for the 5V Regulator (IC 113). The input should be 13.5 V DC, while the output should be 5V DC. Replace if needed.

5. Check the RF Modulator -- test the three input pins to see if a correct signal reaches the part. Replace as necessary. See schematics for pin assignments.

6. Also check and repair/replace the following: FS101; open or shorted traces from CN101 to IC101; open traces on oscillator (OSCI01); and connections to/from IC 102, IC101, and/or CN102.

USING THE TEST JIG

1. First, attach the test jig to the expansion bus on the rear of the TurboGrafx-16 unit. Be sure this connection is firm.

2. Plug the AC cord from the test jig into a wall socket. Then plug the power cord into the TurboGrafx unit.

3. Connect the RF modulator to the TurboGrafx unit. Turn the TV to channel 3 or 4.

4. Insert the diagnostic card into the game card slot. Insert loopback plug into TurboPad connector. Turn on the power switch for both the TurboGrafx unit and the test jig.

The test jig performs a series of 17 tests on the unit. Each test is dependent on the last -- if test 2 fails the unit never goes to test 3. The first four tests will give an audio signal if they fail, but no video image. The remaining test will give an error code. The chart on the following page explains each error code and its respective test. Skip ahead if there is a video image/error code displayed. If there isn't an image, follow the steps below:

Is there power?

   NO: Check for a short between Vcc and ground.
      Check FS101.
   YES: Check for sound output:

   Is there sound?

   NO: Check IC101.
   Check pin 11 (RESET) and pin 10 (OSC).
   Check IC101, pins 17 and 18.
   Check IC101 to CN102.

   YES (long beeping sound): IC102 may be bad
   If so, check traces between IC101 and IC102.
   If check proves negative, try replacing IC102.

   If not (short beeping sound), IC110/IC114 may be bad
   Check trace of IC101 to IC111, IC111 to IC110/114.

   If there is no short beeping sound either, IC112 may be defective (long continuous sound):
   If so, check traces between IC101 and IC112.
   If not, IC101 functions under following conditions:
   Pin 45, IC101 is shorted, or
   IC101, pins 1-6 are shorted, or
   IC101, pins 7-80 are shorted, or
   IC101, pins 64-74 are shorted.
<table>
<thead>
<tr>
<th>Test Item</th>
<th>Error Code</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC111 Interrupt</td>
<td>No Display</td>
<td>Busy signal line (IC101 to IC111)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NMI signal line (CN103 to IC111)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A8-A20 lines</td>
</tr>
<tr>
<td></td>
<td>02-1, 2 **</td>
<td>IRQ1 line (IC101 to IC111)</td>
</tr>
<tr>
<td>Mapping Register</td>
<td>03-1, 2 **</td>
<td>Signal lines of IC101, or IC101</td>
</tr>
<tr>
<td>IC111DMA</td>
<td>04-0 **</td>
<td>DMA Signal lines of IC111, or IC111</td>
</tr>
<tr>
<td>IC111 speed and</td>
<td>05-1 **</td>
<td>Signal lines of IC101, or IC101</td>
</tr>
<tr>
<td>internal interrupts</td>
<td></td>
<td>Signal lines of IC111, or IC111</td>
</tr>
<tr>
<td></td>
<td>05-2 **</td>
<td>HSM line (CN102 to CN103, IC101)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>XWR, A16-A20 lines (CN102 to CN103, IC112, IC111, IC101, IC102)</td>
</tr>
<tr>
<td></td>
<td>05-3 **</td>
<td>Signal lines of IC101, or IC101</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Signal lines of IC111, or IC111</td>
</tr>
<tr>
<td></td>
<td>05-4 **</td>
<td>HSM line (CN102 to CN103, IC101)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>XWR, A16-A20 lines (CN102 to CN103, IC112, IC111, IC101, IC102)</td>
</tr>
<tr>
<td>Address Bus</td>
<td>06-2 ##</td>
<td>A0-A7 (CN102-CN103, ICs 101, 102, 111, 112)</td>
</tr>
<tr>
<td></td>
<td>06-3 ##</td>
<td>A8-A15 (CN102-CN103, ICs 101, 102, 111, 112)</td>
</tr>
<tr>
<td></td>
<td>06-0 ##</td>
<td>XRD (CN102-CN103, ICs 101, 102, 111, 112)</td>
</tr>
<tr>
<td>&quot;##&quot; means the data of address bus when the error occurs. The test program writes &quot;55&quot; or &quot;AA&quot; on address bus.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controller Port</td>
<td>07-1, 2 **</td>
<td>XCARD line (CN102 to CN103)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>XB line (CN103 to IC 101)</td>
</tr>
<tr>
<td></td>
<td>07-3, 4, 5, 6, 7 **</td>
<td>Controller signal lines (IC101 to CN101)</td>
</tr>
<tr>
<td>Audio Output Line</td>
<td>08-1, 2 **</td>
<td>Sound output lines (IC101 to OpAmp, RF mod)</td>
</tr>
<tr>
<td>CRT Signals</td>
<td>09-1 **</td>
<td>SYNC line (IC112 to CN103)</td>
</tr>
<tr>
<td></td>
<td>09-2 **</td>
<td>COMPV line (CN103 to IC112, RF mod)</td>
</tr>
<tr>
<td></td>
<td>09-3/4 **</td>
<td>HSYNC/VSYNC line (CN103 to IC112, IC111)</td>
</tr>
<tr>
<td>Video Data Line</td>
<td>10-1, 2 **</td>
<td>VD lines (CN103 to IC112, IC 111)</td>
</tr>
<tr>
<td>ICI12 External Sync</td>
<td>11-1, 2 **</td>
<td>CSEL line (CN103 to IC112)</td>
</tr>
<tr>
<td>Analog RGB Level</td>
<td>12-1, 2, 3 **</td>
<td>RGB lines (CN103 to IC112)</td>
</tr>
<tr>
<td>CRT Signals</td>
<td>No Display</td>
<td>VD lines (CN103 to IC112, IC111)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RF output line (IC112 to RF mod)</td>
</tr>
<tr>
<td>Sound Check</td>
<td>No Sound</td>
<td>Sound output lines (IC101 to OpAmp, RF mod)</td>
</tr>
<tr>
<td></td>
<td>Two short sounds</td>
<td>Voltage of AGND (IC101)</td>
</tr>
</tbody>
</table>

"*** = (shown on screen) means test has passed
FLOWCHARTS
No Picture On Channel 3 Or 4

Start

- Just snow on channel 3/4?
  - Y: Replace AC adapter.
  - N: Blank screen on channel 3/4?
    - Y: Replace game card. Check connections on CN102.
    - N: FS101 open?
      - Y: Replace FS101.
      - N: D102 OK?
        - N: Replace D102.
        - Y: +13V DC at input of IC113?
          - N: Check C129, C130, power switch, etc. in power supply circuit. Open trace from DC in to IC113.
          - Y: Complete.
  - N: Pass test jig?
    - Y: Complete.
    - N: Start at top of next page.
From previous page

+5V DC at output of IC113?
N Replace IC113.
Y

+5V at RF mod. pin 1?
N Check C129, C130, power switch, etc. in power supply circuit. Open trace from DC in to IC113.
Y

0.8-1.0V at RF mod. pin 2?
N Replace RF mod.
Y

+5V at OSC101?
N Check L103.
Y Open trace from power supply to OSC101.

21.477MHz at pin 10 on IC101?
N Check R102, R103, R104, C107.
Y Open trace from OSC101 to IC101.

21.477MHz at pin 2 on IC112?
N Check R122, C125.
Y

Check the following and replace if necessary: open traces around IC112, IC102-IC112-CN102, IC101, IC111-IC110-IC114.

21.477MHz out of OSC101?
N Replace OSC101.
Y Check components around OSC101.
No Picture, Using Turbobooster

Start

Replace turbobooster. OK?  

Y → Complete.

N

Check CN103 (loose connections). OK?  

Y → Complete.

N

Check the following and replace if necessary:  
open traces around IC101-IC102,  
IC112,  
IC111-IC110.
Check the following:
open traces around IC101-IC106,
IC112,
IC102-IC112-CN102,
IC111-IC110-IC114.
Also check the game card.
Controller Malfunctions

Start

Replace pad. OK?  Y → Complete.

N → Check connections around CN101. OK?

N → Check/replace CN101.

Y → Check pins (loose connections) 31, 32 and 22, 24, 25, 26 of IC101. OK?

N → Open traces from CN101 to IC101.

Y → Replace IC101.
# PIN ASSIGNMENTS

## EXPANSION BUS Interface

<table>
<thead>
<tr>
<th>PIN NO.</th>
<th>NAME</th>
<th>I/O</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>A01</td>
<td>Audio L</td>
<td>O</td>
<td>Audio Output (L channel)</td>
</tr>
<tr>
<td>A02</td>
<td>+5A</td>
<td>O</td>
<td>Power Supply +5V</td>
</tr>
<tr>
<td>A03</td>
<td>CESEL</td>
<td>I</td>
<td>Chip Select 6260</td>
</tr>
<tr>
<td>A04</td>
<td>A18</td>
<td>O</td>
<td>System Address Bus 18</td>
</tr>
<tr>
<td>A05</td>
<td>A14</td>
<td>O</td>
<td>System Address Bus 14</td>
</tr>
<tr>
<td>A06</td>
<td>A9</td>
<td>O</td>
<td>System Address Bus 9</td>
</tr>
<tr>
<td>A07</td>
<td>A10</td>
<td>O</td>
<td>System Address Bus 10</td>
</tr>
<tr>
<td>A08</td>
<td>D6</td>
<td>IO</td>
<td>System Data Bus 6</td>
</tr>
<tr>
<td>A09</td>
<td>DCK</td>
<td>I</td>
<td>Dot Clock</td>
</tr>
<tr>
<td>A10</td>
<td>X V SYNC</td>
<td>I</td>
<td>Vertical Sync</td>
</tr>
<tr>
<td>A11</td>
<td>EXTPOW</td>
<td>I</td>
<td>External Power Supply +10.5V</td>
</tr>
<tr>
<td>A12</td>
<td>SPBG</td>
<td>O</td>
<td>Sprite Data/Background Data</td>
</tr>
<tr>
<td>A13</td>
<td>VD7</td>
<td>O</td>
<td>Video Data Bus 7</td>
</tr>
<tr>
<td>A14</td>
<td>EXTPOW</td>
<td>I</td>
<td>External Power Supply +10.5V</td>
</tr>
<tr>
<td>A15.</td>
<td>VD5</td>
<td>O</td>
<td>Video Data Bus 5</td>
</tr>
<tr>
<td>A16</td>
<td>VD4</td>
<td>O</td>
<td>Video Data Bus 4</td>
</tr>
<tr>
<td>A17</td>
<td>VD3</td>
<td>O</td>
<td>Video Data Bus 3</td>
</tr>
<tr>
<td>A18</td>
<td>VD2</td>
<td>O</td>
<td>Video Data Bus 2</td>
</tr>
<tr>
<td>A19</td>
<td>VD1</td>
<td>O</td>
<td>Video Data Bus 1</td>
</tr>
<tr>
<td>A20</td>
<td>VD0</td>
<td>O</td>
<td>Video Data Bus 0</td>
</tr>
<tr>
<td>A21</td>
<td>OVAG</td>
<td>IO</td>
<td>GND for Analog Circuit</td>
</tr>
<tr>
<td>A22</td>
<td>COMPV</td>
<td>O</td>
<td>Composite Video</td>
</tr>
<tr>
<td>A23</td>
<td>VIDEOR</td>
<td>O</td>
<td>Analog Video Output (Red)</td>
</tr>
</tbody>
</table>

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TurboGrafx-16 Service Manual   15
<table>
<thead>
<tr>
<th>PIN NO.</th>
<th>NAME</th>
<th>I/O</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>B01</td>
<td>AUDIOC</td>
<td>O</td>
<td>Audio Output from Game Card</td>
</tr>
<tr>
<td>B02</td>
<td>XB</td>
<td>I</td>
<td>bit 7 of K port</td>
</tr>
<tr>
<td>B03</td>
<td>HSM</td>
<td>O</td>
<td>High Speed Mode</td>
</tr>
<tr>
<td>B04</td>
<td>XWR</td>
<td>O</td>
<td>Write from CPU</td>
</tr>
<tr>
<td>B05</td>
<td>XNMI</td>
<td>I</td>
<td>Non Maskable Interrupt to CPU</td>
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GAME CARD Connector Pin Assignments

![Diagram of GAME CARD Connector Pin Assignments]
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## PAD Connector Pin Assignments

![PAD Connector Pin Diagram](image)

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TurboBooster
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AC Adapter

SCHEMATICS

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60 Hz

3300uF/16V
DC 10.5V
730 mA