



GPIB Flash Drive User Guide for Tektronix 4050 computers

ABSTRACT

User Guide for my GPIB Flash Drive designed to support Tektronix 4051, 4052/4052A, and 4054/4054A computers.

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1. Background

Tektronix 4051 computer system was introduced in 1975 at the dawn of the personal microcomputer. The 4051 was a complete system including a Motorola 6800 microprocessor, up to 32KB of RAM, 32KB of BASIC ROM, integrated 1024x780 vector graphics with 11-inch direct-view storage tube (DVST) monitor, internal tape drive using 3M DC300 300KB data cartridges, integrated keyboard, graphics hard copy interface, joystick interface, GPIB interface, option ROM backpack with two-slots, and optional RS-232 serial interface.



Figure 1 - Tektronix 4051 computer with optional Tektronix 4924 GPIB tape drive and GPIB cable

I used a Tektronix 4051 for three years at work in the late 1970's and developed several graphics simulation programs including submission of a Cubic Spline Interpolation program to the Tektronix 4050 Application Library. The Tektronix 4051 was one of the first personal computers and was the first personal computer I had ever used. The 4051 can also be considered one of the first personal graphics workstation computers.

I collected and repaired a Tektronix 4052 computer in 2000, followed by a Tektronix 4054 computer, and found two other people that had collected 4051 computers. We began trying to share 4051 tapes we each had with various 4051 games and discovered that duplicating DC300 tapes was the only reliable way to share. As a computer design Electronics Engineer at Compaq Computer, I began trying to use the 4052 integrated GPIB interface connected to my PC

using the parallel port but quickly found the lack of PC support for GPIB made the GPIB interface too difficult to use for computer-to-computer communication.

I then wrote a BASIC program for my Tektronix computer to send files from Tektronix tape over RS-232 to my PC and found that the Tektronix made heavy use of control characters for printing. These control characters were not understood by PC text editors that I had at the time, so my 4050 BASIC program converted all the control characters except CR into a 3-character sequence that I believed would not occur in Tektronix programs: “~X~” where X was the ASCII character typed on the Tektronix with the CTRL key. This serial program was cumbersome to use on more than a couple of files on a tape and was limited to 2400 baud on a 4051 or 9600 baud on the 4052 and 4054 so I did not recover many programs to my PC using this technique. My program also included delays to accommodate time to process the received data and delays to prevent overrunning the 4052 or 4054 if sending a program from the PC.

After copying several tapes and sending them to my new ‘Tektronix 4050’ friends, I lost interest in my Tektronix computers until I discovered and joined the vcfd.org website in 2018 and found a new set of people that had collected and restored Tektronix 4050 computers and had attempted to archive a couple of data tapes to their PCs.

I then dusted off my Tektronix 4052 and 4054 and found they both needed some repairs – but worse than that I found my data tapes that had worked in 2000 had broken tape belts and could not be used. Researching this issue on the web, I found this was common, and although other materials had been tried as data cartridge tape belt replacements – they had mixed results including short life.

During this search I encountered several websites that offered solid state drives as replacement for some vintage computers using these tape cartridges, however it appeared these solid state drives only worked with specific computers – such as vintage HP or Commodore computers, and I could not find anyone that had developed a replacement for the Tektronix 4050 series computer tapes and drive.

I posted on vcfd.org a thread “Tektronix 405x GPIB Flash Drive” in June 2018 and got several strong positive reactions, and in my second post in this thread I referenced a website that had used an Arduino to create a GPIB CONTROLLER. I wired up an Arduino based on their instructions – but the Tektronix 4050 computers could only operate as the GPIB MASTER CONTROLLER and communicate with GPIB DEVICE CONTROLLERS.

I found an interesting GPIB project on eevblog.com called AR488. This project turned an inexpensive Arduino board into a GPIB MASTER CONTROLLER that emulated the commands of a ProLogix GPIB MASTER CONTROLLER. I posted in this thread my interest in developing a GPIB DEVICE CONTROLLER which emulated the Tektronix 4924 GPIB Tape Drive. The author of AR488 accepted the challenge and we have created the Tektronix 4050 GPIB Flash Drive and tested it on a Tektronix 4051, 4052 and 4054A computers using hundreds of programs that I have recovered from Tektronix 4050 tapes, and many programs that I have written.

2. Flash Drive Overview

The Tektronix 4050 GPIB Flash Drive works with the entire series of Tektronix 4050 computers including the 4051, 4052, 4054 and A-Series 4052A and 4054A and does not require an Option ROM Pack to access programs or data. However, some of the programs on the Flash Drive do require option ROM Packs.

I have modified some of the tapes I have recovered to support the Flash Drive. The modifications are relatively simple – change any internal tape command to direct the command to the Flash Drive at GPIB primary address 5. My curated programs for the Flash Drive are posted in my GitHub repository here:

<https://GitHub.com/mmcgraw74/Tektronix-4050-GPIB-Flash-Drive>.

Some of these programs require an optional ROM Pack. One of the most interesting Tektronix ROM Packs is the R12 Graphics Enhancement ROM Pack which provides accelerated vector graphics performance (also called Fast Graphics by the primary author of the R12 ROM Pack) and even plays PWM (pulse-width-modulated) music on the Tektronix 4050 speaker! This ROM Pack was sold by Tektronix for both the 4051 and 4052/4054 computers. However, this R12 ROM PACK is very rare. I found one person with an R12 ROM Pack and borrowed the ROM PACK to download the EPROMs and posted the files to my GitHub repository. I created an R12 ROM Pack by erasing the EPROMs in a 4052 FFT ROM Pack and reprogramming them with the R12 code.

I later worked with Jos Dressen to reverse engineer my 4050E01 8-slot ROM Expander and Jos designed his 4052/4054 Multi-Function ROM Pack that has a single EPROM large enough to hold 8 4052 ROM Packs and he had room to add the 4052 RS-232 Printer Interface hardware and the TransEra RTC-741 Real-Time-Clock hardware based on my help reverse engineering the RTC-741 ROM Pack that I had in my collection. Jos still offers his 4052 Multi-Function ROM Pack to 4052 or 4054 owners.

I also had several 4051 ROM Packs in my collection and captured and uploaded their ROM images to my repository including the 4051R05 BINARY PROGRAM LOADER. This ROM Pack adds the capability for the 4051 to save and load BINARY programs to internal tape or external Tektronix 4924 GPIB Tape Drive. Since the Flash Drive emulates a 4924 GPIB Tape Drive – this R05 ROM Pack allows a 4051 to load and save programs in BINARY format. The BINARY programs load about 3 times faster than ASCII programs – since this format can be copied directly into 4051 RAM without needing to be parsed and tokenized by 4051 BASIC. This is such a big performance improvement that the 4052 and 4054 BASIC included the BINARY PROGRAM Calls in the 4052 and 4054 BASIC ROMs.

Fortunately, vintagetek.org sells a MAXIROM Pack for the 4051 on EBAY that contains the both the Fast Graphics 4051R12 Graphics Enhancement ROM and 4051R05 BINARY Program ROM and eight other 4051 ROM Packs!

Jos also had the Tektronix 4052/4054 Diagnostic ROM Pack which is essential in troubleshooting RAM or ROM errors. He designed an equivalent Diagnostic ROM Pack – which I used to extend the ROM CRC checks to all the option slots and ROM Expander slots – such as the 4050E01 which I have and the Multi-Function ROM Pack which emulates the 4050E01.

Bottom line on the option ROMs – some of the programs I have included in my Flash Drive program image zip file require an option ROM. I have designed the Flash Drive Main Menu program to test your 4050 computer to discover if you have the R05, R12 ROM, RTC ROM, or Diagnostic ROM (the last two are only available for a 4052/4054). Your computer configuration is then saved on a couple of files on the Flash Drive – and are used in the Main Menu to only allow you to run programs that will work on your computer. If you attempt to manually run a program that requires a ROM PACK that you don't have installed, you will get an error message indicating that ROM CALL was not found.

The Flash Drive emulates the internal tape drive as it uses a file number to access a file. The Flash Drive also has a directory feature, which allows multiple “tapes” to be stored on the Flash Drive. The Flash Drive uses a MicroSD card for file storage. In addition, the MicroSD card can removed from the Flash drive and plugged into a PC if the PC has a

MicroSD slot or plugged into a USB to MicroSD adapter (not included) to transfer Flash Drive program or data files to or from the PC or to backup and restore the entire Flash Drive.

You can also add your own directory to the Flash Drive with 4050 BASIC PROGRAM and DATA files.



Figure 2 - 4050 GPIB Flash Drive

The Flash Drive (Figure 2) is a small device that plugs directly into the Tektronix 4050 GPIB connector on the back of every Tektronix 4050 computer. There are no switches for GPIB address configuration – the Flash Drive is set to GPIB primary address 5 in the Flash Drive firmware.

The Flash Drive is powered separately from the Tektronix 4050 by a USB 5V at 500mA or higher current power adapter which is readily available but is not included – as international users need a different power adapter connector than North America users. A USB-A power cord is supplied with the Flash Drive and has a USB MINI-B (5-pin) connector on the other end to plug into the Flash Drive and a USB power adapter.

Flash Drive file storage is provided by a MicroSD flash card plugged into the Flash Drive on the top board in Figure 2. A MicroSD card preloaded with files is supplied with the Flash Drive. This MicroSD card can be easily removed from the Flash Drive by gently pushing the MicroSD card into the connector which will release the catch and the MicroSD card will be released and can be removed from the Flash Drive. This allows the MicroSD card to be connected to a PC to backup or restore all the Flash Drive files or copy files or directories to or from the MicroSD card to a PC.

Making a backup of the Flash Drive files on the MicroSD card with your PC will be useful if you create new files – such as saving a game on the Flash Drive. Having a backup makes it very easy to restore all your program and data files to a MicroSD card if you cannot access a file.

If you get a Tek BASIC message that a Flash Drive file is NOT FOUND, use the instructions in the Troubleshooting Section of this manual to pinpoint what actions you should take.

It is recommended that you plug the Tektronix 4050 computer and the USB power adapter for the Flash Drive into an outlet strip with surge protection.

3. 4050 GPIB Flash Drive Features

The GPIB Flash Drive has the following features:

1. Completely replaces 4050 internal tape drive for ALL program and data storage
2. Ready to run with **400 or more files** in 15 or more 'tape' directories including 35 games and 33 R12/Fast Graphics pictures on the MicroSD card
3. MicroSD card provides Gigabytes of program data and storage
 - a. Plug MicroSD into USB-MicroSD adapter to transfer program & data files to/from your PC
4. Faster access and loading of all files than internal tape
5. Stores each 'tape' in separate directory – 100's of tapes can be stored on same Flash Drive
6. Flash Drive is compatible with **ALL** Tektronix 4051, 4052, 4052A, 4054 and 4054A computers
7. Supports all 4050 BASIC GPIB tape commands:
 - a. FIND, MARK, KILL, OLD, BOLD, SAVE, BSAVE, APPEND, BAPPEN, PRINT, INPUT, READ, WRITE
8. Plugs into 4050 GPIB connector – no Option ROM needed to use the Flash Drive
9. First Time Setup – discovers your 4050 computer model and installed option ROMs
10. Main Menu – organizes access to curated directories and programs
 - a. First Time Setup discovery of installed Options to ensure that Main Menu items are compatible with your 4050 computer detected configuration.
 - b. Options detected include 4050 Model, Memory size, R05 BINARY Program Loader ROM, R12 Graphics Enhancement ROM, 4052 Diagnostic ROM, 4054/4054A Option 30 and TransEra 4052/4054 RTC.
 - c. The Main Menu includes a File Browser selection allowing easy access to all the Flash Drive directories with a TLIST and Change Directory feature. Return to the Main Menu at any time by typing RUN.
11. Flash Drive AUTO LOAD – uses the RTC (Real-Time-Clock) Option (included in the 4052/4054 Multi-Function Option ROM available separately) to AUTO LOAD your 4050 computer at power-on to your Favorite Program and Directory which is the last selection you made from the Main Menu.
12. Flash Drive Micro-USB power cord included.
 - a. USB 5V at 500mA or higher current power adapter is not included as it requires a country specific power connector.
13. One **Flash Drive zip file** with the all the latest 'tapes' and programs can be downloaded from the internet and be unzipped to your MicroSD card to update your Flash Drive:
<https://GitHub.com/mmcgraw74/Tektronix-4050-GPIB-Flash-Drive>
14. Vectrex game controller interface!
15. **New Flash Drive Firmware Feature** – Support for multiple Flash Drives, requires additional TI GPIB buffers connected to Flash Drive – not compatible with current Flash Drive GPIB PCB. Contact me for more details.
16. **Added Flash Drive GPIB Interface board schematic**

The GPIB Flash Drive zip file may include new/updated BASIC programs – listed in the README.

Previous versions of the Flash Drive zip file are moved to the Archive in that directory.

4. Flash Drive Operation

Plug the Flash Drive micro-USB connector into a USB 5V at 500mA or higher current power adapter (not included) and then plug the Flash Drive into the GPIB connector on the back panel of your 4051, 4052 or 4054 computers.

Turn on the 4050 computer. The Flash Drive powers up in the ROOT directory of the MicroSD card, unless you have the RTC Option ROM which provides an AUTO LOAD feature to load file 1 in your Favorite Directory.

Flash Drive Command	Description
FIND@5(,27): X	Opens file number X in the current directory
OLD@5(,4):	Loads an opened flash drive file containing an ASCII program into 4050 memory
CALL "BOLD",5(,71)	Loads an opened flash drive file containing a BINARY program into 4050 memory
SAVE@5(,1):	Saves the current 4050 program to the opened flash drive as ASCII Program
CALL "BSAVE",5(,71)	Saves the current 4050 program to the opened flash drive as BINARY Program
APPEND@5(,4):Y	Appends opened flash drive file containing an ASCII program to line Y in current program
CALL "BAPPEN",5(,71);Y	Appends opened flash drive file containing BINARY Program to line Y in current program
INPUT@5(,13): X\$, Y	Inputs ASCII string or numeric data from an opened flash drive DATA file into the 4050
PRINT@5(,12): X\$, Y	Prints ASCII data into an opened flash drive DATA or NEW file from the 4050
READ@5(,14): X\$, Y	Reads BINARY string or numeric data from an opened flash drive BINARY DATA file into the 4050
WRITE@5(,15): X\$, Y	Writes BINARY string or numeric data into an opened flash drive BINARY DATA or NEW file
TYPE@5(,6): X	Returns the type of the next BINARY data item in the current BINARY DATA file
MARK@5(,28): X, Y	Creates X NEW files of size Y bytes at the opened file# and then marks a new LAST file
KILL@5(,7): X	Finds and marks file X as NEW, does not change any other file
PRINT@5,9: "Directory"	Change to "Directory"
INPUT@5,9: X\$	After a FIND@5:# for a file, then this command returns the current directory string to X\$
INPUT@5,19: X\$	After a FIND@5:# for a file, then this command returns that file header string into X\$
PRINT@5,19: X\$	After a FIND@5:# for a file, then this command replaces the file header string with X\$
INPUT@5,31:X,Y,A,B,C,D	Vectrex joystick controller, returns joystick X and Y and A,B,C,D buttons (1,2,3,4)

Figure 3 - Flash Drive Commands

The Flash Drive software is hard-coded for a GPIB Primary Address of 5 which must be present with all the BASIC keywords in the table above. No Primary Address is needed for accessing files on the internal mag tape drive except for PRINT and INPUT keywords with the tape drive which REQUIRES @33: to be present with those two commands.

The colon or semicolon is required for ALL keywords to the Flash Drive other than CALL "BOLD", "BSAVE", and "BAPPEN" using GPIB Primary Address.

The GPIB Secondary Addresses in orange with parenthesis in the table above are automatically sent by 4050 BASIC to the Flash Drive when that command is used and do not need to be added to those 4050 BASIC keywords in programs. The GPIB Primary and Secondary addresses are the only GPIB bytes transmitted by BASIC for those keywords, and these addresses are decoded by the Flash Drive for those BASIC keywords. When the GPIB Secondary address is NOT in parenthesis it is REQUIRED to be present in the BASIC program: examples: PRINT @5,9 or @5,19 and INPUT @5,9 or @5,19 or @5,31.

The CALL "BOLD", "BSAVE" and "BAPPEN" all automatically send Secondary address 71 when used with a GPIB Primary address. When 71 is offset by $32 + 4$ (OLD/APPEND secondary address) = 17 which is listed as "ALPHASCALE" in the 4050 documentation. Secondary address 71 causes the Flash Drive to transfer in 8-bit BINARY based on the GPIB read or write signal instead of ASCII as used by all the other GPIB commands with EOI termination instead of CR used on all the other ASCII commands to the Flash Drive.

The Flash Drive does not support any other 4050 GPIB Secondary address command not listed in the table above.

The Flash Drive uses the file name as the file header with the file number as the first number in the file name. Easiest way to create a properly formatted filename is to copy an existing Flash Drive filename of the same type (ASCII PROGRAM for example) – changing the file number to the desired file number and editing the comment field. Be careful to not change the location of the ASCII/BINARY or PROGRAM/DATA field. You can test whether the created file name is correct by using the Main Menu “TLIST a DIR” command on that directory.

Here is the format of every Flash Drive filename:

1	ASCII	PROG Main Menu	2826	
				File-size starts at 38 and is automatic
				Comment/filename starts @ 21 and ends at 36
				PROG or DATA starts at 16
				ASCII or BINARY starts at 8
				File number starts at 1

Figure 4 - Flash Drive Filename Format

This format is used by the Flash Drive to properly access the data requests from 4050 BASIC based on the file type. You may notice these character start positions are 1 less than on the tape header locations published in the 4050 BASIC programming reference. In that document the first character is always a space which is illegal in FAT and other filesystems. Our observation is that 4050 BASIC never automatically requests the file header from a 4924 GPIB tape drive using any of the commands in Figure 3. In addition, the 4050 TLIST command only works with the internal tape – not the GPIB 4924, so the MAIN MENU provides a routine to emulate TLIST for the selected Directory. There is also a “TLIST” program in file 119 in every directory. Load and run this file to list all the files in this directory. There is a 4050 BASIC command that can return the current open **internal tape** file header to BASIC: INPUT@5,9:X\$. Note this is the command used by the Flash Drive to return the current DIRECTORY name to BASIC. I preferred to stick with the published 4050 GPIB Secondary Address table which indicates secondary address 9 for DIRECTORY and 19 for TLIST.

The 4924 Tape Drive service manual indicates the 4924 firmware uses the tape file header information to determine how to operate on 4050 BASIC READs and WRITES, so that is how we designed the Flash Drive operation.

There is no Flash Drive command to create or delete directories on the MicroSD. That is easily done by unplugging the flash drive MicroSD card (push gently and remove card from adapter) and plugging it into a USB to MicroSD card reader (not supplied). Plug the MicroSD card reader into your PC and use the PC to create or delete a directory from the Flash Drive MicroSD card. Directory names should be limited to 10 characters.

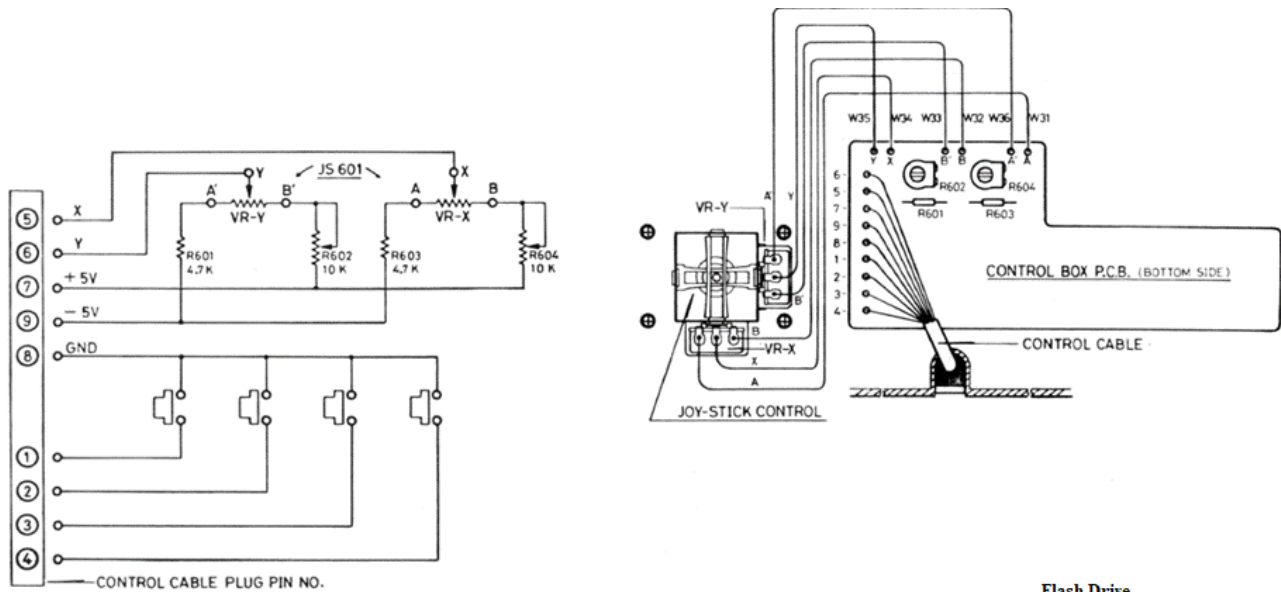
SECRET files are NOT supported in the Flash Drive system.

a. Vectrex joystick controller interface

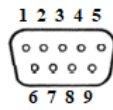
As I was developing my Battlestar Galactica Cylon Attack game for the Tektronix 4054A with Option 30 Dynamic Graphics – I encountered lots of flickering of the Cylon refresh object. Root cause was the Tektronix 4952 joystick interface uses the vector display digital to analog converters to convert the analog joystick X and Y values into digital values with code in Tek 4050 BASIC ROMs. This activity halts the Option 30 display of graphics until the joystick data conversion is complete – resulting in the very visible flickering.

Vectrex was a vector graphics video game system introduced in 1982. Vectrex had a game controller with an analog joystick and four buttons. I have a Vectrex system and decided to see if I could add a Vectrex joystick controller interface to the Flash Drive – by connecting the Vectrex joystick to unused pins on the Flash Drive.

I was successful and have now updated the Flash Drive firmware to add Vectrex joystick support!



Sega Extension Cable (socket)



- 1 Red - Button 1
- 2 Black - Button 2
- 3 Gray - Button 3
- 4 Orange - Button 4
- 5 Brown - X
- 6 Green - Y
- 7 White - +5V for X&Y pots
- 8 Blue - GND for Buttons
- 9 Yellow - GND for X&Y pots

Flash Drive

IDE	Name	Silkscreen
0	PB0	0
1	PB1	1
2	PB2	2
3	PB3	3
A1	PA1	A1
A2	PA2	A2
	5V	5V
	GND	GN
	GND	GN

HAND CONTROL SCHEMATIC

Figure 6 - Vectrex to Sega Extension Cable wiring

FLASH DRIVE Controller **Vectrex Joystick Interface** **Wiring Diagram**

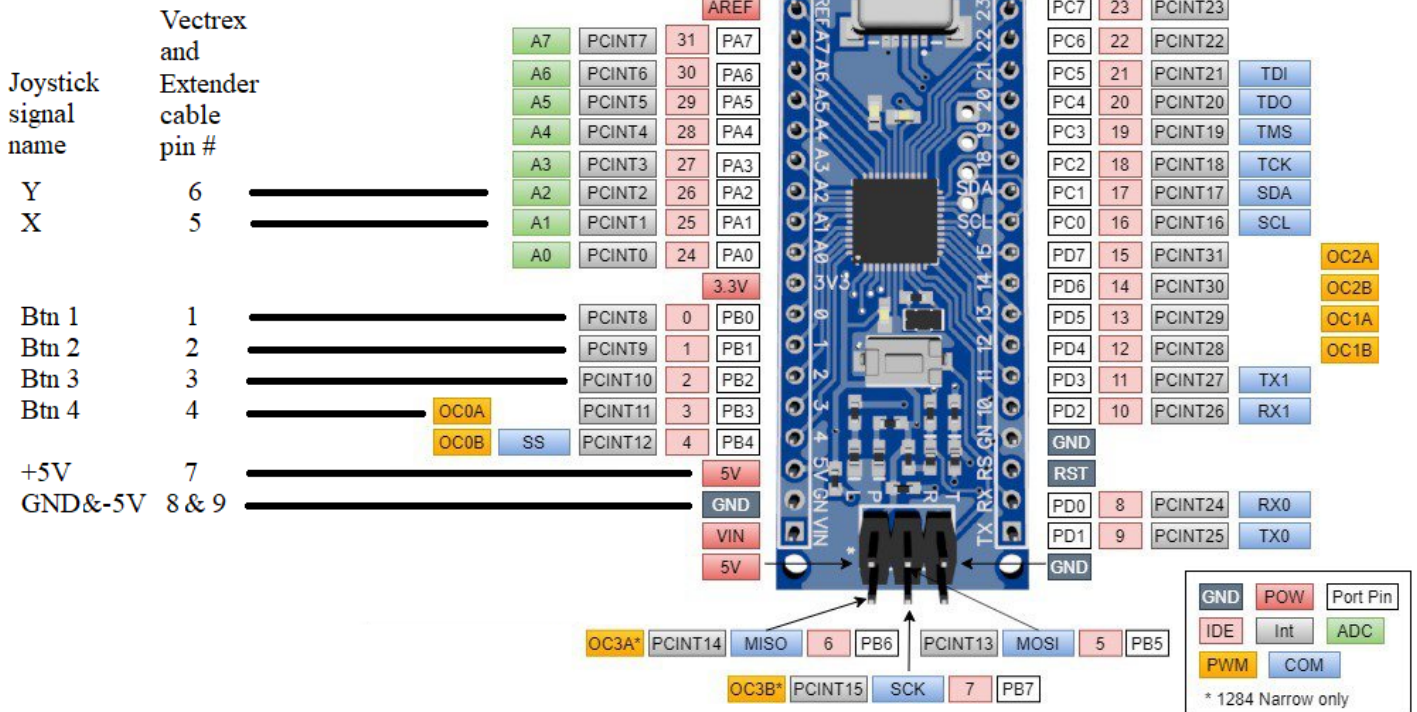


Figure 7 - Flash Drive to Vectrex Joystick Wiring Diagram

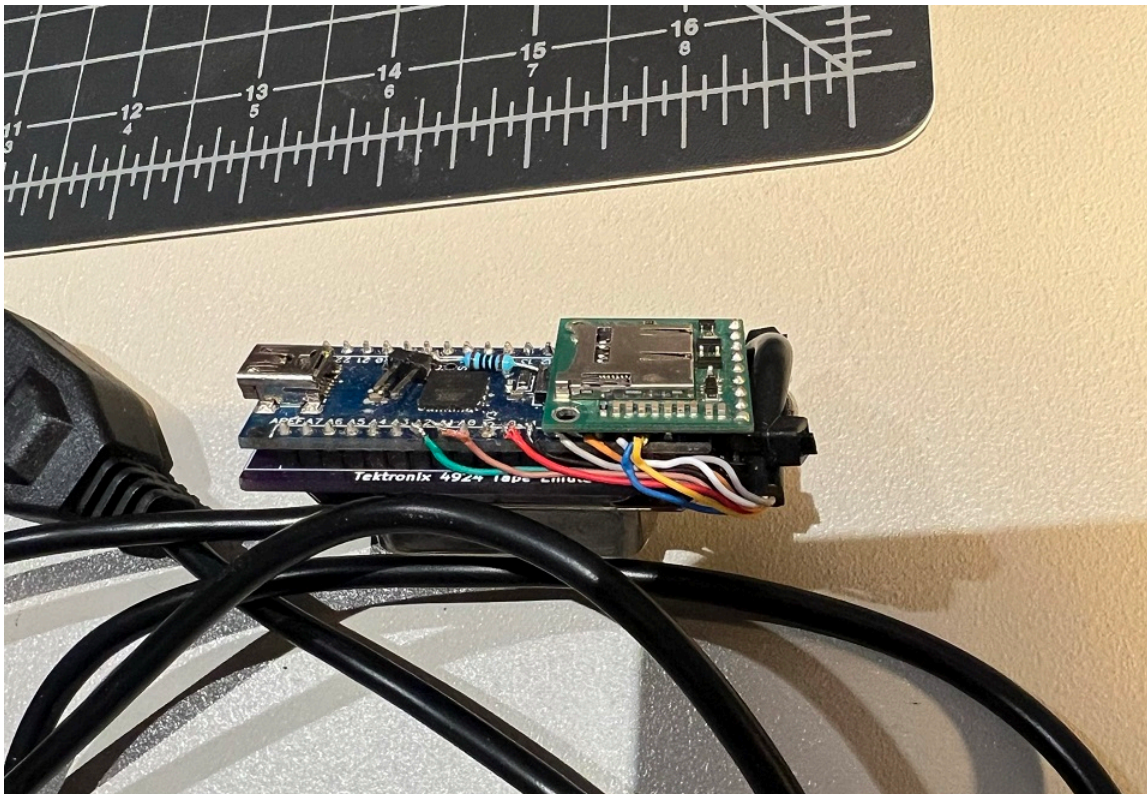


Figure 8 - Flash Drive with Sega Extension Cable

5. First Time Setup of your Flash Drive

First time you power on your 4050 Computer with the Flash Drive plugged into the GPIB connector and powered; the Flash Drive will start in the ROOT directory of the MicroSD card. Type the following to run the Main Menu program:

FIND@5:1

OLD@5:

RUN

You will see the screen PAGE followed by a message "CREATING NEW CONFIG FILES".

Then the program will PAGE again and you will see the First Time Setup screen below:

```
Flash Drive - First Time Setup for your 4052 with 64KB
4052/4052A & 4054/4054A include R05 support in BASIC ROM
Detecting R12 ROM Pack:
  - R12 ROM is required to run R12/Fast Graphics Pictures
If CALL NAME INVALID, Type: RUN 3000 then RETURN key
ABC
R12 ROM Detected
Detecting 4052/4054 TransEra RTC ROM Pack or MFM:
  - RTC ROM is required for RTC Auto Load Feature

If CALL NAME INVALID, Type: RUN 4000 then RETURN key

CALL NAME INVALID IN LINE 3110 - MESSAGE NUMBER 32
█
```

Figure 9 - First Time Setup on 4052

First Time Setup automatically discovers and prints on the top line of this screen:

4050 Model Name	4051, 4052, 4052A, 4054, or 4054A
Memory Size	32KB or 64KB
Option 30	Only available on 4054 or 4054A

Next the program tries to detect the following Option ROM Packs:

R05 BINARY PROGRAM LOADER	4051 only, included in 4052/4052A and 4054/4054A BASIC ROM
---------------------------	--

R12 GRAPHICS ENHANCEMENT	4051 MAXIROM or 4052/4054 and A-Series Multi-Function ROM PACK
RTC TransEra Real-Time Clock	4052/4054 and A-Series Multi-Function ROM PACK
Diagnostic ROM Pack	4052/4054 and A-Series Diagnostic ROM PACK

Option ROM Pack discovery is more difficult because the program must try to execute one of the ROM Pack commands. If you don't have that ROM Pack installed, you will get a BASIC error message "CALL NAME INVALID IN LINE XXXX", like the last line in Figure 9. In order continue to attempt to discover other Option ROMs, the program prints a message before trying to run a ROM Pack command:

IF **CALL NAME INVALID** IN LINE XXXX, Type **RUN YYYY** then **RETURN** key

If the ROM PACK is detected – example **R12 ROM Detected** in Figure 9, the program automatically proceeds to test the next Option ROM PACK in the list above. For the 4051 option ROM tests only the R05 and R12 ROM Packs are tested. For all the other 4050 models, all four option ROM Packs are tested.

```

F
Flash Drive - First Time Setup for your 4052 with 64KB
4052/4052A & 4054/4054A include R05 support in BASIC ROM
Detecting R12 ROM Pack:
- R12 ROM is required to run R12/Fast Graphics Pictures
If CALL NAME INVALID, Type: RUN 3000 then RETURN key
ABC
R12 ROM Detected
Detecting 4052/4054 TransEra RTC ROM Pack or MFM:
- RTC ROM is required for RTC Auto Load Feature

If CALL NAME INVALID, Type: RUN 4000 then RETURN key

CALL NAME INVALID IN LINE 3110 - MESSAGE NUMBER 32
RUN4000
Detecting 4052/4054 Diagnostic ROM Pack:
- Diagnostic ROM is required for 4052/4054 Checksums

If CALL NAME INVALID, Type: RUN 5000 then RETURN key

CALL NAME INVALID IN LINE 4190 - MESSAGE NUMBER 32
RUN 5000

Option Discovery is Complete.

```

Figure 10 - First Time Setup Discovery is Complete

Figure 10 shows the screen when First Time Setup Option ROM Discovery is Complete. In this example on my 4052 the R12 ROM was detected, and the program immediately continued to attempt to detect the RTC ROM without needing to print a CALL NAME INVALID error message. However, the program did not detect an RTC ROM, nor did it detect a Diagnostic ROM, so in both of those cases there was a CALL NAME INVALID error message and I typed RUN YYYY based on the program printed instructions prior to the error message, for every Option ROM not detected.

WARNING: If the First Time Setup program fails to detect the R05, R12, RTC or Diagnostic ROM and prints the error message and stops: please be sure to type **RUN** before the **YYYY** line number or you will delete line **YYYY** in the Main Menu program and then you will have to clear the discovery CONFIGURATION file 123 and reload the MAIN MENU file 1 by typing the following commands. You also need to use these commands if you move the Flash Drive to a different 4050 computer or add or remove an Option ROM Pack.

FIND@5:123

PRINT@5:0

FIND@5:1

OLD@5:

RUN

Note: you may see the blinking F in the top left corner of the display at the end of Option Discovery as shown in Figure 10. This is typical 4050 BASIC behavior when the screen is FULL. Manually **PAGE** the screen to continue to the MAIN MENU.

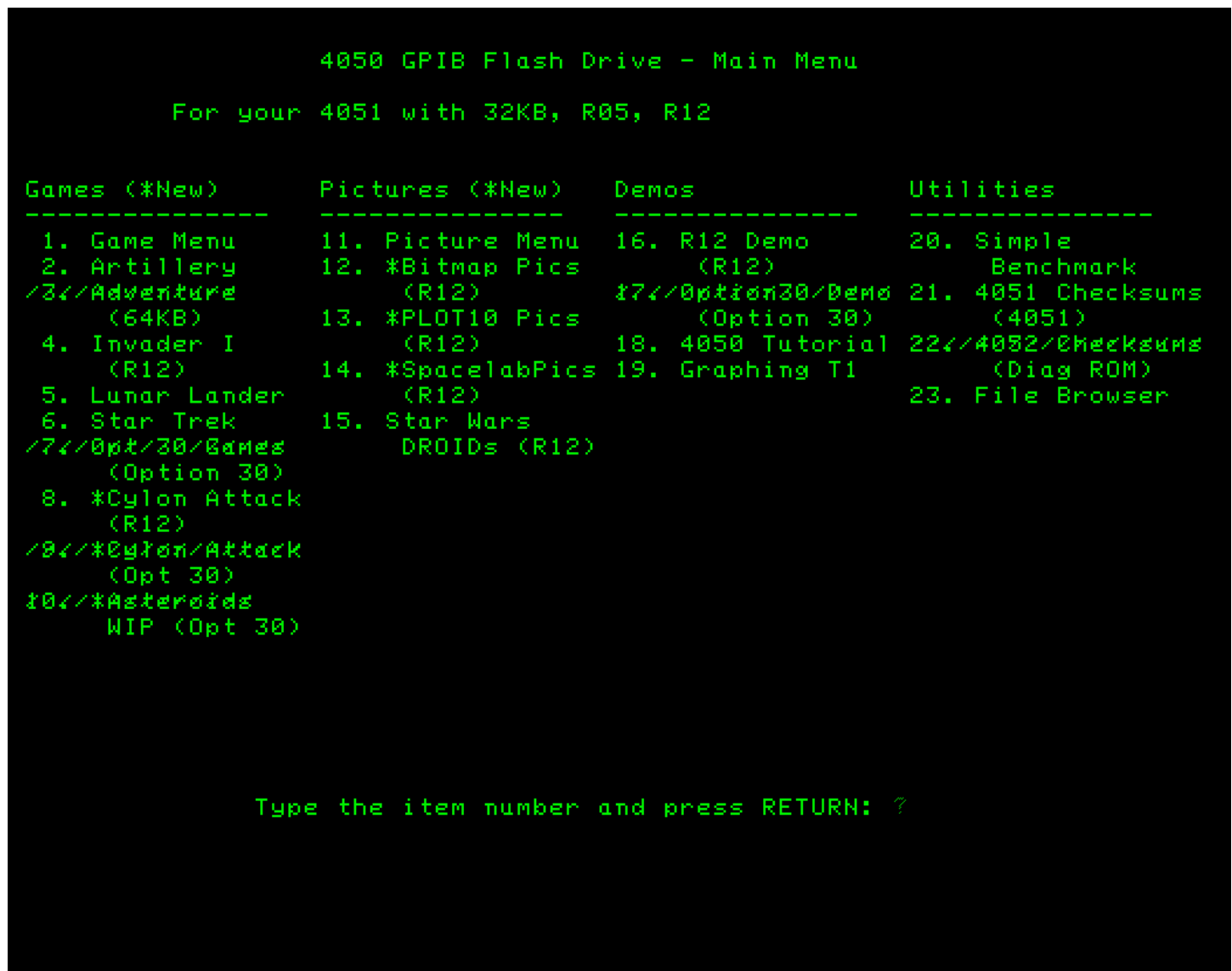


Figure 11 - Flash Drive Main Menu

Figure 11 shows the Main Menu. The Main Menu will be used to access any of the programs or other Menus in the Flash Drive using the instructions in section 6 “Use the Flash Drive”. First Time Setup will only be run once – and the detected configuration including all detected Options will always be displayed at the top of the Main Menu.

If the RTC ROM was detected on your 4052 or 4054 or A-Series computer, your computer will AUTO LOAD file 1 in the last directory you selected from the Main Menu – when your computer is powered on. This is the Flash Drive AUTO LOAD “Favorite Directory” feature.

Note that Main Menu items will be marked unavailable with “/” over the name for any Main Menu item that requires an Option that is not detected during First Time Setup. The name of the required Option will be listed in parenthesis after the name of that menu item.

For example: Figure 11 shows my 4054A computer with 64KB of RAM, R05, R12, and RTC Options detected.

If a particular Option ROM is not installed, or in the case of item 15 in Figure 11 requires 4051 for compatibility with that program, then the Main Menu will mark the item as unavailable. Only the menu items that are not marked with / can be selected by the Main Menu to provide friendly use to untrained 4050 computer users.

Another example in Figure 11 is item 4 – Adventure, which I ported to the 4050 computers from a Commodore PET BASIC program. Since Adventure for PET made extensive use of integer variables and string arrays – which are not in 4050 BASIC – my port requires 64KB of RAM and will therefore not run on a 4051 which had a maximum of 32KB of RAM.

As new Flash Drive image zip files are published, the Main Menu will be updated in the zip file to increase the number of menu items.

Some of the menu file 1 programs in directories like Picture Menu include a menu selection to continuously display all the pictures in sequence for an unattended demo. Two versions of Picture Menu are available in Figure 11 – selecting 2 will launch the version that will be accelerated graphics using the R12 option ROM. Selecting 3 will launch the version that does not require the R12 option ROM – but the vector drawing speed will be substantially slower.

New to this Flash Drive image is a File Browser – selection 17. The File Browser allows the user to TLIST a directory, Change to a different Directory or return to the Main Menu by typing RUN as shown in the following Figure.

File Browser

Press User Definable Key (UDK) to operate:

UDK 1 - TLIST current directory

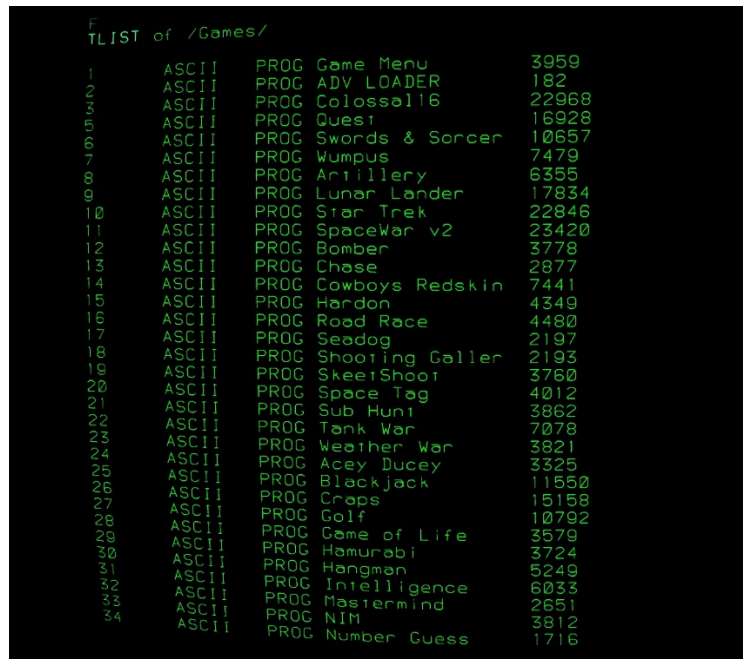
UDK 2 - Change Directory

UDK 20 - (Shift UDK 10) RUN File 1 in current Directory

Type RUN to return to the MAIN MENU

Figure 12 - File Browser

Pressing User Definable Key (UDK) 1 will PAGE the screen and display the current directory TLIST of files.



F TLIST of /Games/				
1	ASCII	PROG	Game Menu	3959
2	ASCII	PROG	ADV LOADER	182
3	ASCII	PROG	Colossal16	22968
4	ASCII	PROG	Quest	16928
5	ASCII	PROG	Swords & Sorcer	10657
6	ASCII	PROG	Wumpus	7479
7	ASCII	PROG	Artillery	6355
8	ASCII	PROG	Lunar Lander	17834
9	ASCII	PROG	Star Trek	22846
10	ASCII	PROG	SpaceWar v2	23420
11	ASCII	PROG	Bomber	3778
12	ASCII	PROG	Chase	2877
13	ASCII	PROG	Cowboys Redskin	7441
14	ASCII	PROG	Hardon	4349
15	ASCII	PROG	Road Race	4480
16	ASCII	PROG	Seadog	2197
17	ASCII	PROG	Shooting Galler	2193
18	ASCII	PROG	SkeetShoot	3760
19	ASCII	PROG	Space Tag	4012
20	ASCII	PROG	Sub Hunt	3862
21	ASCII	PROG	Tank War	7078
22	ASCII	PROG	Weather War	3821
23	ASCII	PROG	Acey Ducey	3325
24	ASCII	PROG	Blackjack	11550
25	ASCII	PROG	Crops	15158
26	ASCII	PROG	Golf	10792
27	ASCII	PROG	Game of Life	3579
28	ASCII	PROG	Hamurabi	3724
29	ASCII	PROG	Hangman	5249
30	ASCII	PROG	Intelligence	6033
31	ASCII	PROG	Mastermind	2651
32	ASCII	PROG	NIM	3812
33	ASCII	PROG	Number Guess	1716
34	ASCII	PROG		

Figure 13 - TLIST

Pressing UDK 2 will PAGE the screen and display the list of Flash Drive directories. Type the directory number and press RETURN to change to that directory as shown in the next Figure:

```
Change Dir from /root/ to:

1  ADV4052
2  Adventure
3  Games
4  GraphngT1
5  GrpR12demo
6  Op130Demo
7  Op130Games
8  Pictures
9  R12o30Demo
10 R12IceRace
11 Root
12 SVG2FG
13 SysTape
14 Utilities

INPUT the number to CD or just RETURN to not change: 3
Changed to Games

UDK 1 - TLIST current directory
UDK 2 - Change Directory
UDK 20 - (Shift UDK 10) RUN File 1 in current Directory

Type RUN to return to the MAIN MENU
```

Figure 14 - Change Directory

Note the “F” above the word TLIST in Figure 13. This F will be blinking when text has filled the screen. Press the PAGE key to clear the screen.

Pressing UDK 20 which is accessed by pressing the SHIFT key and UDK 10 will RUN file 1 in the current directory.

6. Use the Flash Drive

Plug the Flash Drive micro-USB connector into a USB 5V at 500mA or higher current power adapter (not included) and then plug the Flash Drive into the GPIB connector on the back panel of your 4051, 4052 or 4054 computer.

Turn on the 4050 computer. The Flash Drive starts in the ROOT directory of the MicroSD card when Flash Drive is powered up (unless the RTC is present – and the Flash Drive AUTO LOAD will load file 1 in the Favorite directory).

Type the following 4050 BASIC immediate commands to load and run the MAIN MENU:

FIND@5:1

OLD@5:

RUN

You should see the Flash Drive Main Menu:

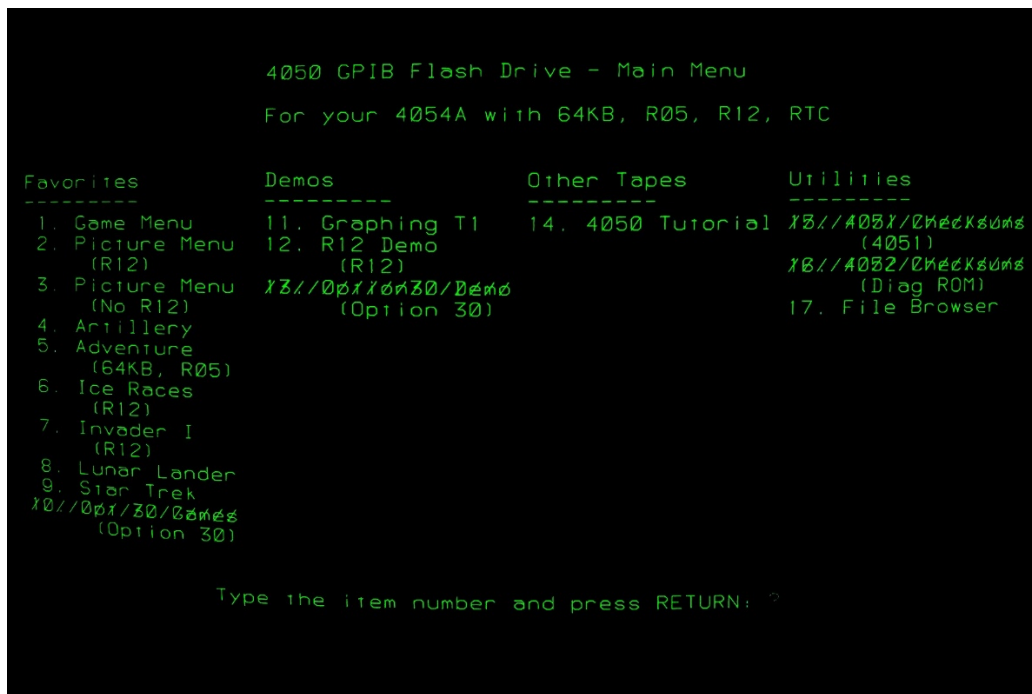


Figure 15 - Flash Drive Main Menu in ROOT directory

Most of the Main Menu items change to a different directory and either run a menu for that directory or a single program from a different directory than the ROOT directory which contains the Main Menu.

Simply type the item number and press RETURN to run the selected program.

Most of the programs on the Flash Drive have a quit or exit function that should return to a menu or to the MAIN MENU.

If a program doesn't have that feature, press BREAK twice and type the following statements to run the MAIN MENU.:

PRINT@5,9:"ROOT"

FIND@5:1

OLD@5:

RUN

7. Flash Drive hardware

The Flash Drive is comprised of three circuit boards:

1. CONTROLLER: Pandauino 644-Narrow or 1284-Narrow running the Flash Drive CONTROLLER firmware
2. MicroSD Adapter: Pololu #2587 MicroSD Card adapter with Level Shifter. Uses any GB size MicroSD Card
3. Tektronix 4050 Flash Drive GPIB Interface: connects CONTROLLER, MicroSD adapter and GPIB connector

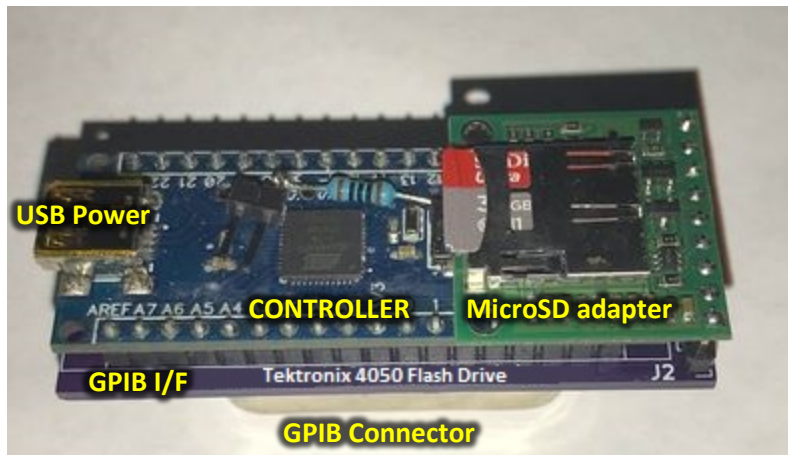


Figure 16 - Flash Drive hardware

8. Micro SD card files

The default directories and files on the Flash Drive MicroSD card are preinstalled.

Any updates to these files or directories will be uploaded as a FlashDrive.zip file to:

<https://GitHub.com/mmcgraw74/Tektronix-4050-GPIB-Flash-Drive>

and here:

https://GitHub.com/mmcgraw74/Tektronix-4051-4052-4054-Program-Files/Flash_Drive

Easiest way to freshen or restore the Flash Drive directories and files is to delete all the directories and files from the MicroSD card using your PC and then unzip the FlashDrive.zip file to the MicroSD card.

9. Flash Drive firmware

The Flash Drive firmware is preloaded into the Flash Drive CONTROLLER for Flash Drives that are pre-assembled. Updates to the Flash Drive firmware will be posted in this directory:

[Flash Drive - Arduino Code](#)

The Flash Drive CONTROLLER firmware can be updated from a PC with MicroSD slot or USB-MicroSD adapter using Arduino IDE software installed on your PC with the MightyCore added to Arduino IDE Board Manager and then adding the narrow directory to MightyCore variants directory following the Pandauino user manual page 8:

[644-1284-Narrow_user's_manual_v1.0.pdf](#)

1. I followed the mrguen user manual directions for Option B - MODIFY THE MIGHTYCORE AUTOMATIC INSTALL, although I am running Arduino IDE 1.8.19 and MightyCore 2.2.2 since version 3.x does not support this board.
 - I copied the narrow and wide folders from mrguen's 644-Narrow repository to my laptop:
C:\Users\<username>\AppData\Local\Arduino15\packages\MightyCore\hardware\avr\2.2.2\variants.
This folder already had bobduino, sanguino, and standard folders
2. I then followed the next user manual step - although the instruction is not very clear: "by adding these lines where appropriate"
 - I opened the mrguen boards.txt and the
C:\Users\<username>\AppData\Local\Arduino15\packages\MightyCore\hardware\avr\2.2.2\boards.txt
file in Notepad++ and compared them and found the narrow and wide statements were only in the Pinouts section.
 - C:\Users\<username>\AppData\Local\Arduino15\packages\MightyCore\hardware\avr\2.2.2\boards.txt
file already had bobduino, sanguino and standard statements in that section, so I simply added the narrow and wide statements to the MightyCore board.txt file. I have not seen an mrguen "644-Wide" board, but I put those statements in anyway.
 - I then saved the edited MightyCore board.txt file.
3. Since I had the Arduino IDE open while I was editing the board.txt file - I closed the Arduino IDE and reopened it and now was able to select Tools | Board | MightyCore | ATmega644. Then reopen Tools | Pinout and select the Narrow pinout for the ATmega644. If you are using the 1284-Narrow board then you select ATmega1284 as the board and make sure the Pinout is Narrow.
4. Now try testing by selecting the File | Examples | 01. Basics | Blink in the Arduino IDE with your 644 or 1284 board configured from step 3 with the correct port selected.
5. Click Sketch | Upload to have the IDE compile the Blink program and upload it to your Flash Drive board over USB.
 - If the upload is successful – you should see the ORANGE LED blink at 1 blink per second
 - The avrdude programming software checks for the selected device and throws an error if the device is a 1284 and you selected 644 and vice-versa.
6. Now you can load the Flash Drive program which is currently AR488_Store-master22April 2024.
7. You can test this program using the Arduino Serial Console configured at 115200 baud by typing a couple of Flash Drive serial debug commands after unplugging and plugging the Flash Drive with MicroSD card formatted for FAT 32 filesystem and loaded with the latest FlashDrive.zip file:
 - Plug the Flash Drive into USB from the PC with the Serial Console open you should see this message:
 - AR488-Store ready (device).
 - If there is no serial console message and the ORANGE LED is ON – check that you have a MicroSD card installed including all the directories and files from the FlashDrive.zip file
 1. If not – unplug the Flash Drive USB cable, insert a formatted and programmed MicroSD and then plug the USB cable back into the Flash Drive and you should see the AR488-Store ready (device) message on the serial console.

- Type ++ver on the top line in the Serial Console and then the ENTER key – or click SEND button
 - AR488 GPIB storage ***Device 5***, /w Gamepad, ver. 0.05.90, 22/04/2024
- Check that the MicroSD contains the files in the ROOT directory. Type ++tlist and press ENTER
 - | | | | | | | |
|-----|--------|------|------|----------|--------|-------|
| 1 | ASCII | PROG | Root | Menu | Loader | 1427 |
| 2 | BINARY | PROG | MAIN | MENU | binary | 15072 |
| 3 | ASCII | PROG | 4051 | Checksum | | 11683 |
| 4 | ASCII | PROG | 4052 | Checksum | | 5983 |
| 5 | ASCII | PROG | MAIN | Menu | | 13316 |
| 6 | ASCII | PROG | RTC | Test | | 4724 |
| ... | | | | | | |
| 124 | LAST | | | | | 0 |
- 8. Unplug the Flash Drive from the PC and plug it into the 4050 for full testing
- 9. Type the following commands to load and run the Flash Drive MAIN MENU program:
 - FIND@5:1
 - OLD@5:
 - RUN

Enjoy using your FLASH DRIVE with your 4050 computer!

10. Flash Drive board assembly

Tektronix 4050 Flash Drive – COMPONENT Bill of Materials:

1. **CONTROLLER (A1):** Pandauino 644-Narrow (Tindie link below)
 - a. <https://www.tindie.com/products/pandauino/644-narrow-atmega644-arduino-compatible-board>
 - b. or CS-1284-Narrow (mouser.com may still stock this)
2. **GPIB Connector (J1):** Norcomp 111-024-113L001 (mouser.com or digikey.com)
3. **Micro SD (M1):** Pololu #2587 MicroSD board with Level Shifter (+ MicroSD card 1GB+)
4. **GPIB Interface PCB v1A** (PCB updated to move the ISP connector holes for easier assembly)
 - a. https://oshpark.com/shared_projects/2MMEkWC5
 - b. Or download PCB gerbers.zip from oshpark link above and upload to jlcpcb or other PCB fab

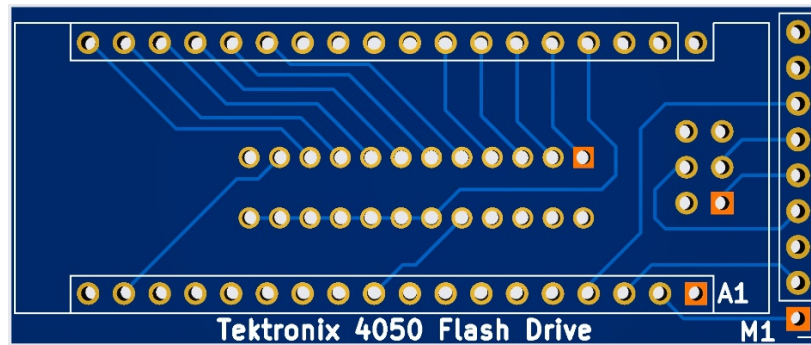


Figure 17 - GPIB Interface PCB v1A TOP

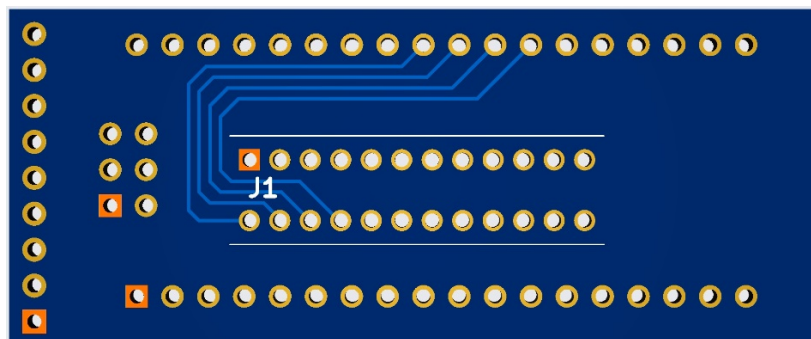


Figure 18 - GPIB Interface PCB v1A BOTTOM

- Both 3D PCB images show Pin 1 of each COMPONENT connector marked in ORANGE and that pin on the PCB is also a SQUARE solder pad.
- The connector name is printed on the PCB side that the COMPONENT will be inserted.
- The six holes in the PCB with no connector name are the CONTROLLER board ISP connector which will be unsoldered from the top of the CONTROLLER board and inserted into the top of CONTROLLER board with the long pins inserted into the GPIB Interface board.

NOTE: The version 1a Flash Drive assembly steps are different from the original GPIB Interface PCB steps. You may be able to use these new instructions to assemble the original GPIB Interface PCB although the ISP header holes do NOT line up and the ISP pins would need to be bent vertical on top of the CONTROLLER after step 4 before you can remove the dry fit CONTROLLER in step 5 below.

Tektronix 4050 GPIB Flash Drive v1a Assembly steps:

1. Unsolder the six pin ISP header from the bottom side of the CONTROLLER board and remove the ISP header.
2. **Dry Fit** – but do not solder, the short unsoldered pins of the ISP header into the TOP of the GPIB Interface PCB v1A with the long pins facing up.
3. **Dry Fit** – but do not solder, the CONTROLLER pins into the GPIB Interface PCB v1A TOP including the dry fit ISP header pins. The ISP header plastic block should be sandwiched between the bottom of the CONTROLLER board and top of the GPIB Interface PCB v1A.
4. Solder the ISP header pins into the BOTTOM of the GPIB Interface PCB v1A while keeping the Dry fit CONTROLLER and GPIB Interface PCB v1A pressed together.
5. Remove the Dry Fit CONTROLLER from the GPIB Interface PCB v1A.
6. Carefully pry the ISP header plastic block off the ISP pins and set the ISP plastic block aside for later assembly.
7. Insert the “wide side” of the GPIB connector with Pin 1 (marked in the connector plastic) into the bottom of the GPIB Interface PCB v1A PIN 1 square pad near the J1 label.
8. Solder the GPIB connector on the TOP side of the GPIB Interface PCB v1A.
9. Trim the GPIB Connector excess leads on the top side of the GPIB Interface board to prevent interference with the components on the bottom side of the CONTROLLER board. See Figure 19.



Figure 19 - GPIB Interface PCB v1A with GPIB connector and ISP Header installed

10. Insert the CONTROLLER board header pins into the GPIB Interface PCB v1A ensuring that the ISP header pins soldered into the GPIB Interface PCB are inserted into the CONTROLLER holes for the ISP header.
11. Solder the CONTROLLER board header pins to the bottom of the GPIB Interface PCB v1A.
12. Trim the CONTROLLER board header pins to prevent interference with the metal shell of the GPIB connector.
13. Solder the ISP pins on the top of the CONTROLLER board and then trim the ISP header pins. See Figure 20.

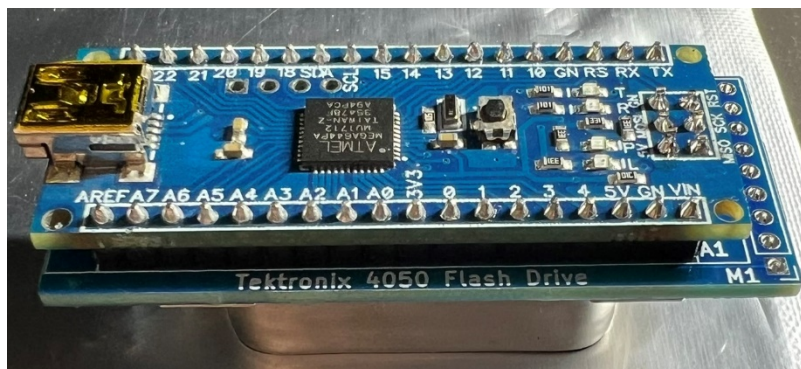


Figure 20 - CONTROLLER assembled to GPIB Interface PCB v1A and ISP header pins soldered and trimmed

14. Place the ISP header plastic on top of the CONTROLLER trimmed ISP pins with the flat side of the plastic up. You may need to trim the soldered ISP header pins closer to the CONTROLLER board so the ISP header plastic block sits flush with the top of the CONTROLLER board.
15. Insert the MicroSD header in the top of the GPIB Interface board v1A holes marked M1 and tack a little solder on the two end pins of the header on the bottom of the GPIB Interface board v1A.
16. Insert the MicroSD board into the MicroSD header above the CONTROLLER board and resting on top of the ISP header plastic block.
17. Align the MicroSD board parallel with the CONTROLLER board by tacking a little solder on the two outer pins of the MicroSD header pins by reheating the tacked solder adjusting the MicroSD board position. It may be necessary to reheat and adjust the MicroSD header at the GPIB Interface PCB to move the header closer to the MicroSD board.
18. Solder the MicroSD header to the top of the MicroSD board and bottom of the GPIB Interface PCB v1A to complete the Tektronix 4050 Flash Drive board assembly. See Figure 21.

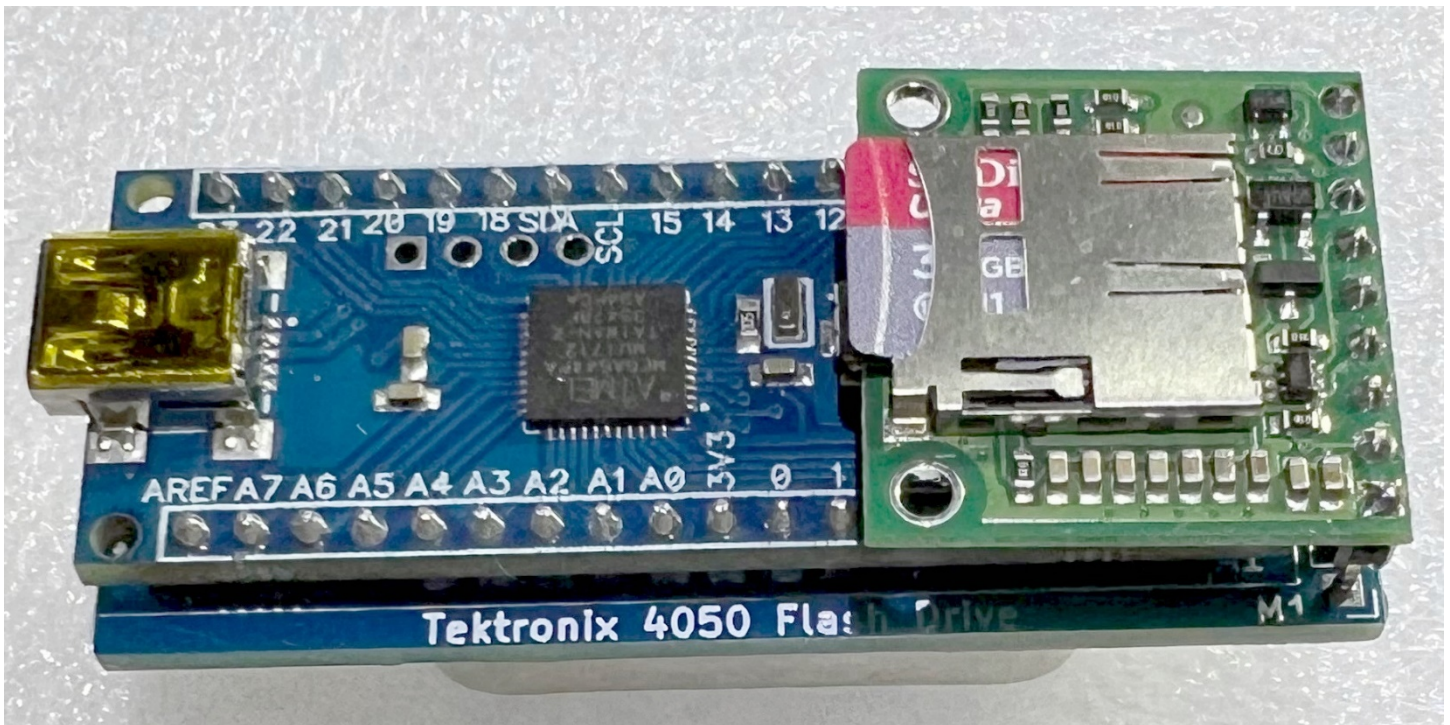


Figure 21 - Assembled Tektronix 4050 Flash Drive

19. Follow the instructions in section 9 Flash Drive firmware to load the latest firmware into your board.
20. Format a MicroSD card as FAT32 to enable long filename support.
21. Unzip the latest Flash Drive zip file from this site: <https://github.com/mmcgraw74/Tektronix-4050-GPIB-Flash-Drive> into your formatted MicroSD card and plug it into your Flash Drive

NOTES:

1. To remove the MicroSD card in the future, **first unplug the Flash Drive power cable**, then remove the MicroSD card from the Flash Drive by gently pushing on the exposed end of the MicroSD card and the MicroSD card will be released from the Flash Drive MicroSD adapter connector and can then be removed from the Flash Drive.

2. Replace the MicroSD card in the unpowered Flash Drive MicroSD adapter socket until it clicks. Then plug USB power cable into the Flash Drive. The default MicroSD folder is ROOT after USB power is applied. This step can be done with the Flash Drive plugged into the 4050 GPIB connector and 4050 powered on.

11. Troubleshooting

Highly Recommended: print out the 4050 Series BASIC Reference Guide June 1983 booklet. This booklet includes all the 4050 BASIC commands for the 4051, 4052, 4054, 4052A and 4054A computers including the Error Messages:



Figure 22 - 4050 Series BASIC Reference Guide

http://www.bitsavers.org/pdf/tektronix/405x/070-2142-02_Tek_4050_Series_Basic_Reference_Jun83.pdf

12. Flash Drive File Not Found

1. Plug the Flash Drive USB power connector into a USB power adapter 5V at 500mA or higher current.
 - a. You should see the Flash Drive BLUE power LED light ON.
 - i. If **Flash Drive BLUE LED is not ON** – check that the USB power adapter is working.
 - ii. If the Flash Drive ORANGE LED is ON – check that MicroSD is present and has files.
2. Plug the Flash Drive into the 4050 computer GPIB connector and ensure it is fully seated in the GPIB connector.
3. Power on the Tektronix 4050 computer.
4. Type these two commands into the 4050:
 - a. **INPUT @5,19:A\$**
 - i. If you see **GPIB I/O Bus Error – Message 69** check the following reasons!
 1. The Flash Drive is not plugged into the 4050 GPIB connector
 2. The Flash Drive is not powered on the Flash Drive USB connector
 3. The Micro SD is not FAT32 formatted
 4. Flash Drive Micro SD does not contain the files from the zip on GitHub
 - a. NOTE: if /ROOT is missing from the MicroSD the firmware will halt
 - b. A\$
5. You should see ROOT printed to the 4050 screen. This is the default directory for the Flash Drive after Flash Drive power-on.
6. Type these commands into the 4050:
 - a. **FIND @5:1**
 - b. **OLD @5:**
 - i. **If you see No Program Found – Error 59** the MicroSD card is not installed in the Flash Drive or the MicroSD card does not have Flash Drive files installed.
 - c. LIST
7. You should see the Flash Drive ROOT Main Menu program listing on the 4050 screen.

8. If the File NOT Found error message occurred on a file that was not in the ROOT directory, type the following commands to change to the ROOT directory and run the Main Menu program:
 - a. **PRINT@5,9:"ROOT"**
 - b. **FIND@5:1**
 - c. **OLD@5:**

a. GPIB I/O Bus Error - Message 69

1. If this error occurs after the Flash Drive has been working, try steps in 11.a.4 above.
2. If you still get a Message 69, unplug Flash Drive power cable, then plug Flash Drive power cable back and check steps 11.a.1 through 7.

b. No files found on MicroSD plugged into PC

1. If this error occurs after the Flash Drive has been working the MicroSD card may need to be reformatted and the directories and files reinstalled from the FlashDrive.zip file
2. A recommended free utility is here: <https://www.sdcard.org/downloads/formatter/> Quick Format as FAT32 selected to reformat the MicroSD card with this utility.
3. Use the Restore MicroSD image steps in 10d to install the Flash Drive files either from a backup.zip that you have created or an image zip file from the Flash Drive web site.

c. CALL INVALID – Message 32

1. This error indicates a ROM Pack is missing or not working. This message should include the line number with the error. Type that line number and press the 4050 keyboard “Recall Line” key (see Figure 23) to see what ROM CALL was not found. If you don’t have that ROM Pack or 4051 MAXIROM or 4052/4054 MFM ROM Pack you will not be able to run this 4050 program.

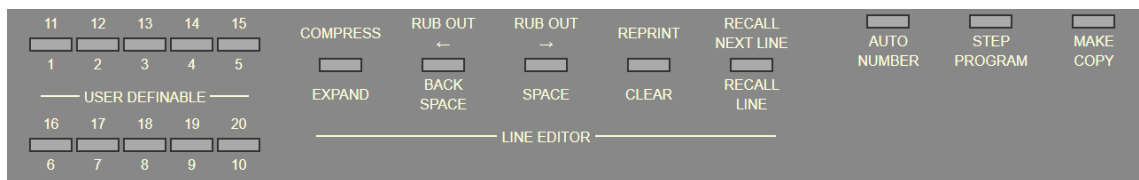


Figure 23 - Tektronix 4050 keyboard User Definable and Editing keys

13. Flash Drive NOTES

a. Flash Drive Power On/Off

- i. **Always unplug the Flash Drive power cable before removing or inserting the MicroSD card.**
 - a. Then gently push on the exposed end of the MicroSD card and the MicroSD card will be released from the Flash Drive MicroSD adapter connector and can then be removed from the Flash Drive.
 - b. Insert the MicroSD card in the unpowered Flash Drive MicroSD adapter socket until it clicks. Then plug USB power cable into the Flash Drive.
- ii. The default MicroSD folder is ROOT after USB power is applied to the Flash Drive.
- iii. If the Flash Drive is powered on when the 4050 is power cycled – the Flash Drive will remain in the same directory.
- iv. The Flash Drive USB power may be unplugged or connected while the 4050 is powered on or off.
- v. The unpowered Flash Drive can be plugged into the 4050 GPIB connector while the 4050 is powered on or off.

b. Flash Drive 'TLIST'

- i. 4050 BASIC TLIST command only supports the internal tape drive, not a GPIB tape drive like the 4924 or Flash Drive. The Main Menu in ROOT provides a TLIST routine that can read Flash Drive file headers and print a "TLIST" to the screen.
- ii. In addition – each directory includes a file 119 TLIST program that can be loaded and RUN to display files in that directory.

c. Flash Drive 'Change Directory'

- i. The Flash Drive emulates a 4050 Tape Changer. All the files on each 'tape' are saved in FAT32 directories on the MicroSD card. Since there was no 4050 BASIC command to "change directory", the Flash Drive supports changing directory with a PRINT @5,9:"directory" command where "directory" is one of the directories on the MicroSD card.
- ii. The Flash Drive MAIN MENU "TLIST" program also allows you view the Flash Drive directories used by the MAIN MENU and change to a different Flash Drive directory.
- iii. There is no Flash Drive command to create, delete, or rename directories. This can be done with the MicroSD plugged into your PC.

d. Flash Drive File Header Description/Comment field

- i. Maximum of 15 characters – no \ or / characters
- ii. Upper or Lower Case insensitive, alpha and numeric characters ok

e. Flash Drive Directory Names

- i. Maximum of 10 characters – no \ or / characters
- ii. Upper or Lower Case letters including spaces, minus sign, underline, and numbers are ok

f. Flash Drive file numbers do not have to be contiguous

- i. The Flash Drive supports non-contiguous file "numbers".
- ii. The Flash Drive 'TLIST' routine in ROOT Main Menu file 1 skips file numbers that are missing and stops when it finds a "LAST" file.

- iii. This feature allows special files like RTC AUTO LOAD program to be stored at the same file 121, regardless of how many files are needed in a particular directory. The largest number of files encountered on tapes I have recovered is 104 on the Tektronix 4050 System Software Tape.

g. Flash Drive “MARK” command

- i. 4050 BASIC MARK command and the Flash Drive requires a FIND command to open the existing file to overwrite, and the size and optionally number of the required file(s) in bytes. Typically, this command is executed starting with the LAST file.
- ii. If the MARK command is executed on any file other than the LAST file - will result in THAT file and ALL subsequent files being overwritten and followed by a LAST file.
- iii. Since the default Flash Drive image has a file 119 for TLIST, file 121 for RTC AUTO LOAD, and file 124 for LAST in every directory (plus a couple more files in the ROOT directory), the easiest way to create files with lower file numbers without using the MARK command is to move the Flash Drive microSD card to the PC with a USB adapter (not supplied) and copy the LAST file in the ROOT directory to the desired directory and change the file number to the file number desired and change the type from LAST to NEW – ensuring that if the file number is not 3-digits to insert spaces to keep the file type at the proper location. Make sure you add a space when editing the file type from LAST to NEW to preserve the character location of the ASCII/BINARY program type field.

h. Using the 4051 Emulator with Flash Drive support to develop programs

- i. This emulator runs in your PC web browser and allows you to drag your 4051 ASCII program or DATA file into the Storage pop-up window of the 4051 Emulator that supports Flash Drive and 4051 Option ROMs located here: <https://GitHub.com/mmcgraw74/Tektronix-4051-Emulator>
- ii. Follow the installation and use directions in the README on that webpage.
- iii. The 4051 Emulator will run ALL the Flash Drive programs supported by the 4051 and includes the 4051R05 BINARY PROGRAM, 4051R12 Fast Graphics Option ROMs and several other ROMs.

i. Program does not have a return to Menu command

- i. Some of the programs don't have a way to quit, or return to a Menu. Simply press the BREAK key twice to stop the program. Then type the following four commands to return to the ROOT Menu:

PRINT@5,9:"ROOT"

FIND@5:1

OLD@5:

RUN

j. Connecting other GPIB Devices with Flash Drive connected to the 4050

- i. Requires Flash Drive hardware and firmware changes using Arduino IDE. Contact me for details at mmcgraw74@gmail.com

14. Flash Drive AUTO LOAD

a. Tape AUTO LOAD

- i. The 4050 computers with tape inserted into the internal tape drive slot will rewind the tape to the beginning and attempt to automatically load and run tape file 1 (if an ASCII Program) when the computer is powered on. This feature only works with the internal tape drive and is NOT supported on the Flash Drive.

b. Flash Drive AUTO LOAD with 4052 Multi-Function Module TransEra RTC

- i. The 4052/4054 Multi-Function Module from Jos Dreesen includes a TransEra 741-RTC Real-Time-Clock module with CR2032 battery backup. One of the features of this RTC is a "Power Up String" command listed on page 5-4 of the manual that I scanned and uploaded to my Tektronix 4050 Program repository:

https://GitHub.com/mmcgraw74/Tektronix-4051-4052-4054-Program-Files/TransEra_ROM_Packs/TransEra_741_RTC_Real_Time_Clock/TransEra_741-RTC_Operators_Manual_1.0_May1983.pdf

- ii. Here is the Flash Drive RTC AUTO LOAD string that I created - note the elimination of SPACE characters in the string to reduce the string length. The 4050 keyboard typeahead buffer is only 28 characters according to the RTC manual. This string stored in the RTC will be pushed into the 4050 keyboard typeahead buffer when the 4050 is powered on. I selected file 121 for the RTC AUTO LOAD program since the tape with the largest number of files in my repository is the 4050 System Software Tape (SysTape directory on the Flash Drive image) with 105 files including LAST.

Tektronix 4050 AUTO LOAD STRING pushed into the keyboard typeahead buffer by the RTC ROM:

1FIN@5:121

2OLD@5:

RUN

Here is the 4050 BASIC program I wrote to send this string into the MFM RTC. Note that the CR character must be inserted into the string with a REP statement replacing the SPACE character for each line of the program including the RUN statement:

```
100 B$=CHR(13)
110 A$="1FIN@5:121 2OLD@5: RUN "
120 A$=REP(B$,11,1)
130 A$=REP(B$,19,1)
140 A$=REP(B$,23,1)
150 CALL "!SETPU",A$,1
```


- iii. Here is the 4050 BASIC program I saved to Flash Drive ROOT file 121 for the RTC AUTO LOAD string to execute. Note this program is 182 characters – far larger than the 28 character limit for the 4050 keyboard typeahead buffer:

```
100 REM  program file 121 in EVERY directory
110 INIT
120 CALL "!PAUSE",10
130 PRINT@5,9:"ROOT"
140 FIND@5:120
150 INPUT@5:D$
155 INPUT@5:F
160 PRINT @5,9:D$
170 FIND @5:F
180 OLD@5:
```

Line 120 delays the program by 10 seconds with an RTC call to allow the 4050 DVST to warm up

Line 130 changes the directory to ROOT

Line 140 opens file 120 which contains the Favorite Directory

Line 150 fetches the Favorite Directory string

Line 155 fetches the Favorite Program file number

Line 160 changes the directory to the Favorite Directory

Line 170 opens file F in the Favorite Directory

Line 180 loads the program and automatically RUNs that program

Flash Drive AUTO LOAD to Favorite Program feature will change the Flash Drive directory at the next power-up of the Tektronix 4050 computer to the Favorite Directory – regardless of whether the Flash Drive remained powered-on while the 4050 was powered off.

15. Support

Post requests for assembled Flash Drives, Flash Drive bug reports, comments or feature requests in this thread:

<https://forum.vcfed.org/index.php?threads/tektronix-4050-gpib-flash-drive-now-available.1238891/>

16. Flash Drive GPIB Interface PCB Schematic

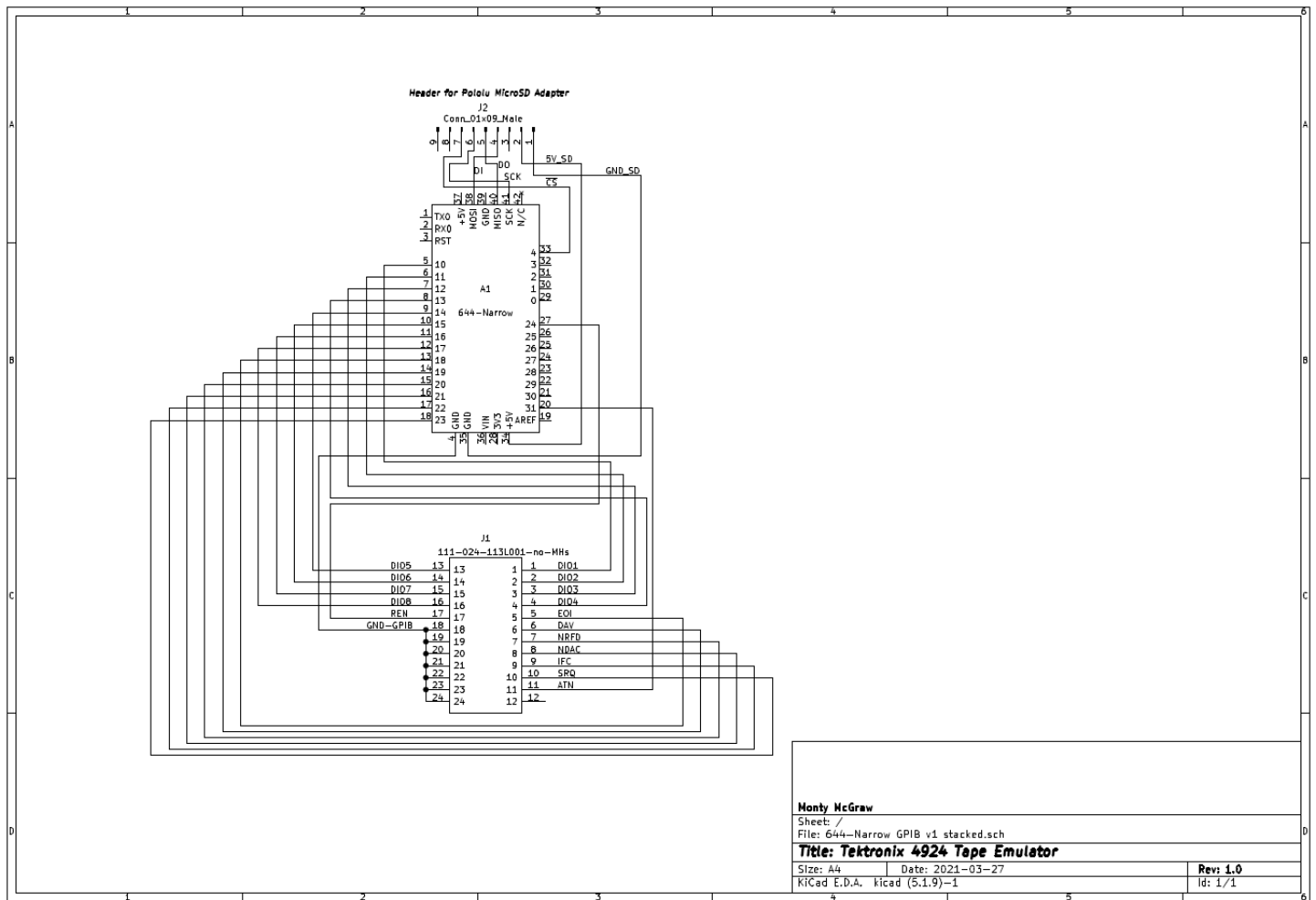


Figure 24 - Flash Drive GPIB Interface PCB Schematic