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 controls 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 vcfed.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 vcfed.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-4051-4052-4054-Program-Files/tree/master/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, following the instructions in section 12f of this document.

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 1A power adapter which is readily available but is not supplied – 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 **500 or more files** in 15 '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. 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 all installed directories and programs and uses First Time Setup discovery of installed Option ROMs to only allow you to select and run programs compatible with your 4050 computer detected configuration.
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 Directory which is the last directory you selected from the Main Menu
12. Flash Drive Micro-USB power cord included. USB 5V 1A 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.

4. Flash Drive Operation

Plug the Flash Drive micro-USB connector into a USB 5V @ 1A power supply (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, 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: X	Opens file number X in the current directory
OLD@5:	Loads an opened flash drive file containing an ASCII program into 4050 memory
CALL "BOLD",5	Loads an opened flash drive file containing a BINARY program into 4050 memory
SAVE@5:	Saves the current 4050 program to the opened flash drive as ASCII Program
CALL "BSAVE",5	Saves the current 4050 program to the opened flash drive as BINARY Program
APPEND@5:	Appends opened flash drive file containing an ASCII program on current program
CALL "BAPPEN",5;Y	Appends opened flash drive file containing BINARY program to line Y in current program
INPUT@5: X$, Y	Inputs ASCII string or numeric data from an opened flash drive DATA file into the 4050
PRINT@5: X$, Y	Prints ASCII data into an opened flash drive DATA or NEW file from the 4050
READ@5: X$, Y	Reads BINARY string or numeric data from an opened flash drive DATA file into the 4050
WRITE@5: X$, Y	Writes BINARY string or numeric data into an opened flash drive DATA or NEW file
TYPE@5: X	Returns the type of the next BINARY data item in the current BINARY DATA file
MARK@5: X, Y	Creates X NEW files of size Y bytes at the opened file# and then marks a new LAST file
KILL@5: 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: this will return the current directory string into X$
INPUT@5,19: X$	After a FIND@5: this will return that file header string into X$
PRINT@5,19: X$	After a FIND@5: this will replace the file header string with X$

Figure 3 - Flash Drive Commands

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:

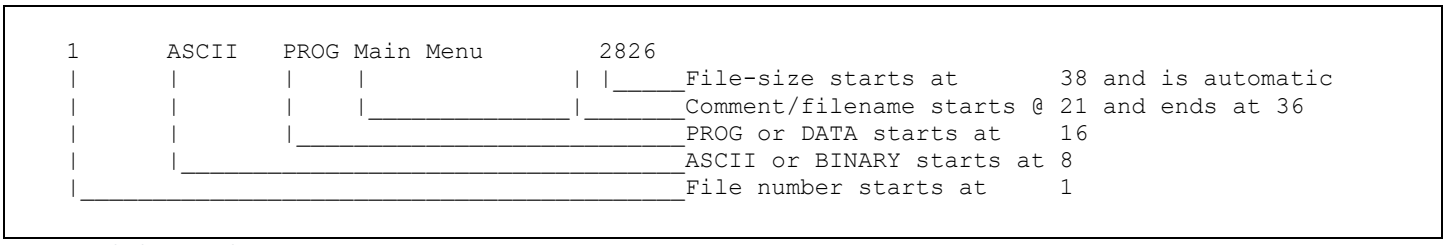

Figure 4 - Flash Drive Filename Format

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 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 4924 tape, so the MAIN MENU provides a routine to emulate TLIST for the selected 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.

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:

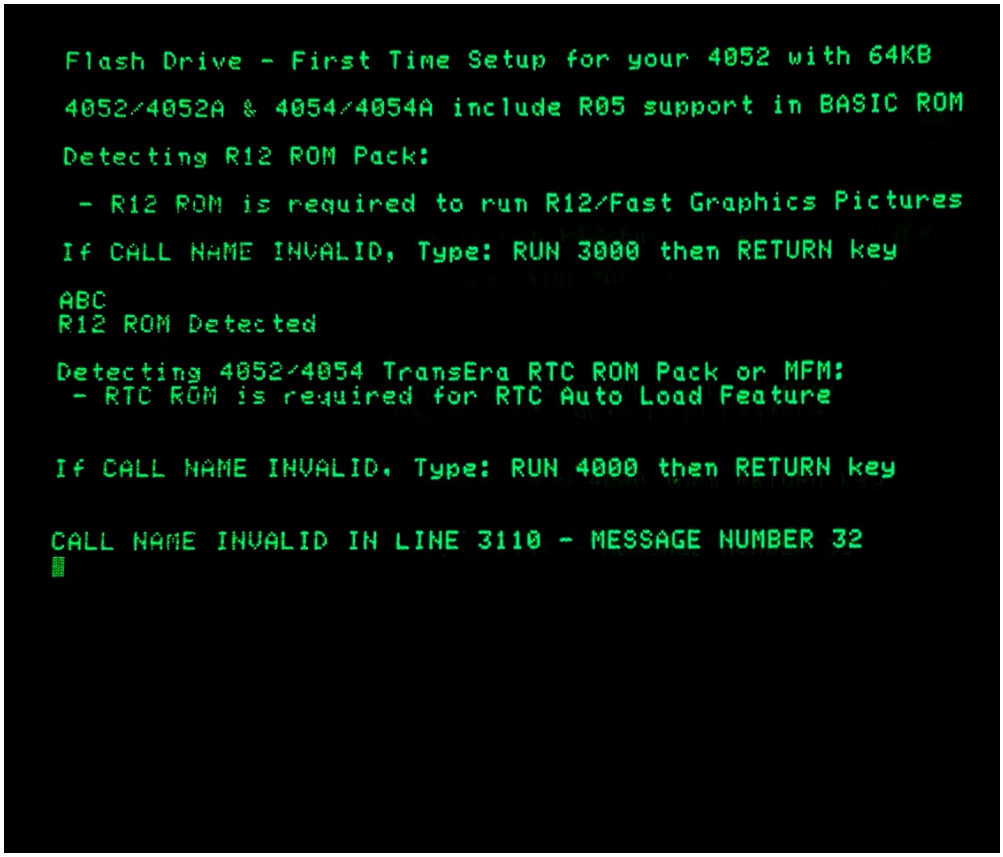

Figure 5 - First Time Setup on 4052

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, standard 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 5. 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 5, 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.

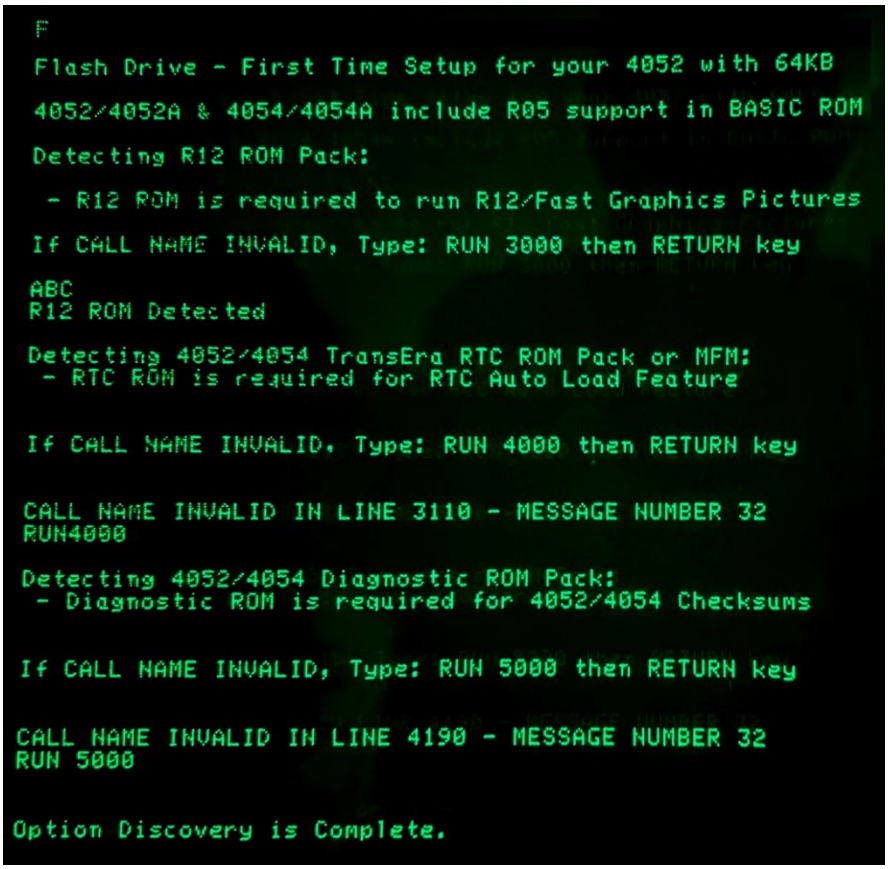

Figure 6 - First Time Setup Discovery is Complete

Figure 6 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 6. This is typical 4050 BASIC behavior when the screen is FULL. Manually **`PAGE`** the screen to continue to the MAIN MENU.

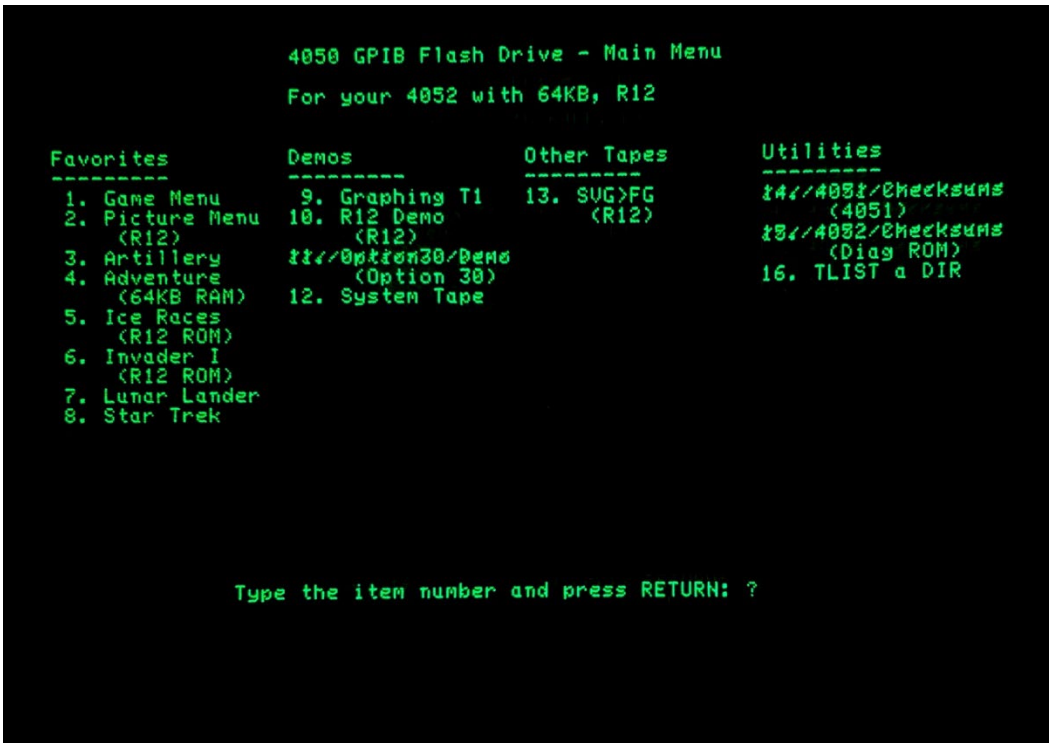

Figure 7 - Flash Drive Main Menu

Figure 7 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 Option ROM Packs 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 ROM – which will be listed in parenthesis after the name of that menu item.

For example: Figure 7 shows my 4052 computer with 64KB of RAM and R12 Option ROM detected.

If a particular Option ROM is not installed, or in the case of item 14 in Figure 7 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 7 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 takes more than 32KB 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 R12 Picture Menu include a menu selection to continuously display all the pictures in sequence for an unattended demo.

6. Use the Flash Drive

Plug the Flash Drive micro-USB connector into a USB 5V @ 1A power supply (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:

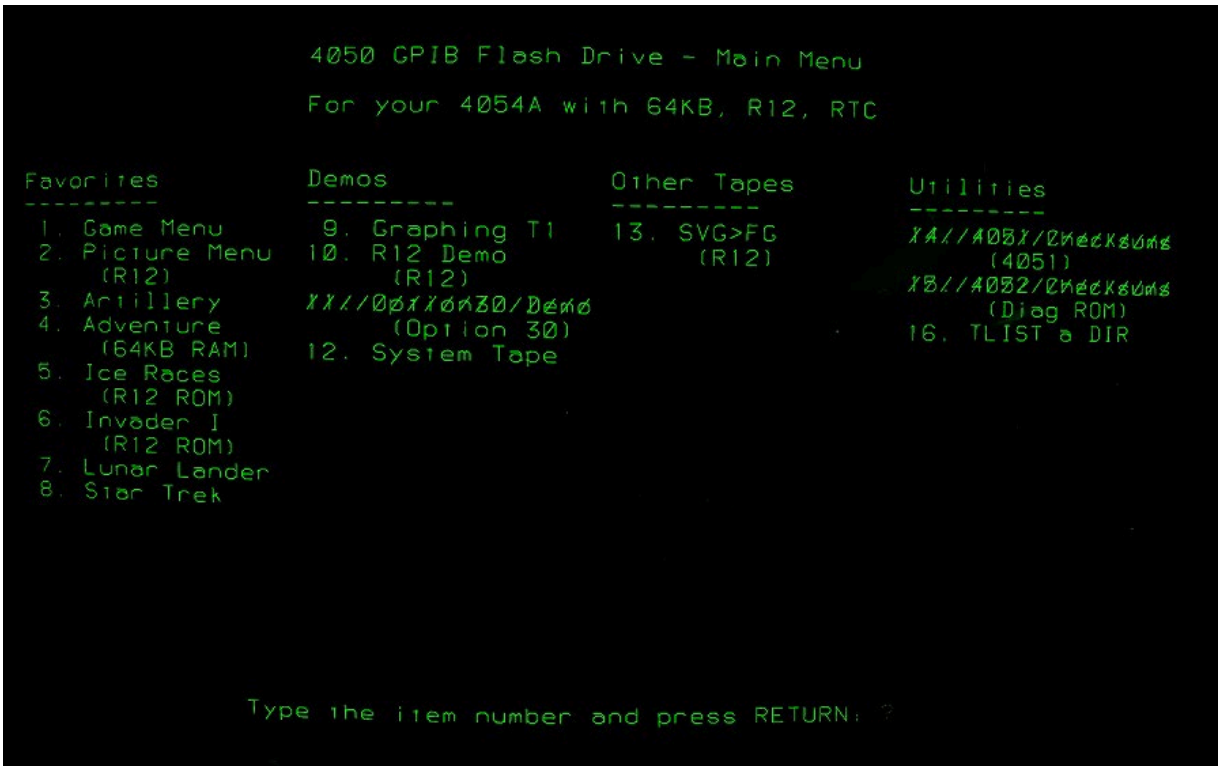

Figure 8 - Flash Drive Main Menu in ROOT directory

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

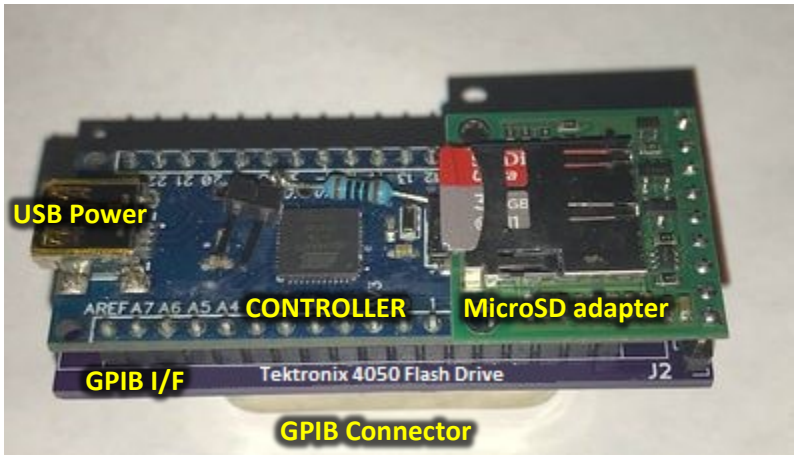

Figure 9 - Flash Drive hardware

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-4051-4052-4054-Program-Files/tree/master/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:

https://github.com/mmcgraw74/Tektronix-4051-4052-4054-Program-Files/tree/master/Flash_Drive/AR488_Store

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 link below added to Board Manager and selecting your controller board – typically ATmega644 (although ATmega1284 can also be used) - using the included Micro-USB cable.

https://mcudude.github.io/MightyCore/package_MCUdude_MightyCore_index.json

10. Flash Drive board assembly

BOM:
1. CS-Narrow-644 (or 1284) board (mouser.com)
2. 111-024-113L001 GPIB connector (mouser.com)
3. #2587 MicroSD board with Level Shifter (Pololu.com)
4. Tektronix 4050 Flash Drive interface board: https://oshpark.com/shared_projects/HIeNjLBF

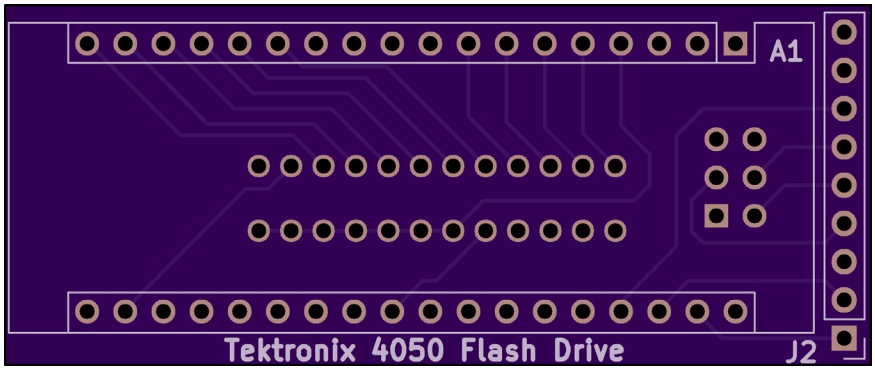

Figure 10- GPIB Interface Board TOP

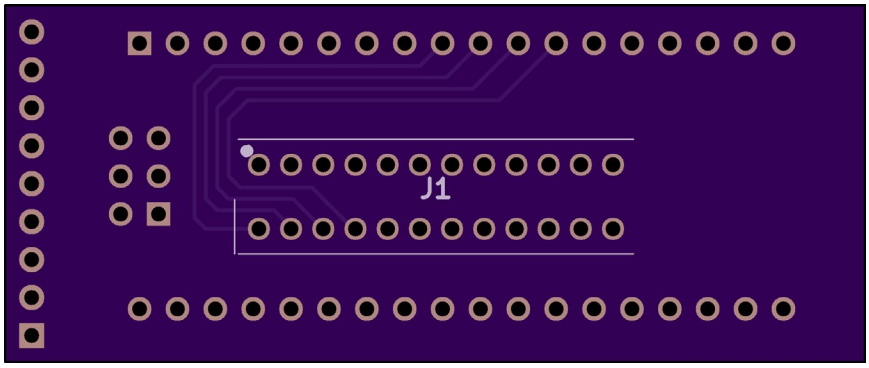

Figure 11- GPIB Interface board BOTTOM

a. Solder the GPIB connector to the GPIB Interface board bottom side with the J1 connector label. Insert the "wide" part of the GPIB connector on the same side as the J1 connector PIN 1 dot. Trim the excess leads on the top side of the GPIB Interface board to prevent interference with the CONTROLLER board.
b. The CONTROLLER 644-Narrow and 1284-Narrow boards come with headers installed. The CONTROLLER is soldered to the pins in the A1 outline in Figure 10. The CONTROLLER connects to the two 18-pin outer headers and the inner six pins on the programming connector – so first melt the solder on one of the 6 inner pins on the CONTROLLER at a time and push that pin toward the bottom side of the CONTROLLER board. I pushed the pins only far enough to extend slightly from the GPIB connector side of the GPIB interface board. Then I clipped the pins on the top side of the CONTROLLER after I removed the 6-pin black plastic header spacer so each pin was slightly shorter than the height of the spacer and then reinstalled the spacer to prevent shorts on those pins with the MicroSD adapter board. Later, that spacer will also help keep the MicroSD card parallel to the Flash Drive Controller board.
    i. Once all six programming pins are moved down (be sure to check all these pins are still soldered to the CONTROLLER) – try to fit the CONTROLLER pins into the 'top' side of the GPIB interface board A1 outline. The programming pins that were moved down in step b will need to be slightly bent to fit in the GPIB interface board. I didn't have the correct offset of those holes when I designed my GPIB interface board. You may have to clean these 6 pins first with solder wick to remove factory solder

that sticks to the pin when you push the pin down, otherwise the solder may keep the pin from being inserted into the GPIB interface board.

ii. Tack solder the four corner pins of the two outside rows on CONTROLLER board to the GPIB interface board to hold those boards in place. You will need to slightly bend the CONTROLLER pins that are touching the GPIB connector away from the GPIB connector to get both the CONTROLLER 18-pin header spacers to sit flush with the GPIB interface board.

iii. Solder the CONTROLLER programming pins to the GPIB interface board - between the GPIB connector and the 4050 Flash Drive interface board.

iv. Solder all the remaining CONTROLLER pins to the GPIB interface board and trim the excess leads on the GPIB connector side of the interface board to prevent shorts with the GPIB connector.

c. Solder the Pololu MicroSD adapter to the interface board J2 connector outline with the included header pins so the MicroSD adapter is parallel to the CONTROLLER board with the adapter components away from the CONTROLLER board and with the adapter resting on the programming pin black spacer and parallel to the CONTROLLER board.

d. Unzip the Flash Drive zip file to install all the directories and files onto the MicroSD card plugged either directly into the PC or plugged into a MicroSD adapter. Then first use the PC software to eject the MicroSD card from your PC – to ensure that all the files have been written to the MicroSD card. Now the MicroSD card can be safely removed from your PC. Install the MicroSD card into the connector on the Flash Drive MicroSD adapter (MicroSD label away from the CONTROLLER as in Figure 9) by gently pushing the MicroSD into the connector and it should lock into position where the MicroSD card is only slightly visible as in Figure 9.

e. Connect the Flash Drive CONTROLLER with the USB cable to your PC and upload the flash drive code

f. Board assembly is complete

NOTE: To remove the MicroSD card in the future, first unplug the Flash Drive power cable, then remove the Flash Drive from the 4050 computer. Now 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.

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 12 - 4050 Series BASIC Reference Guide

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

a. Flash Drive File Not Found

1. Plug the Flash Drive USB power connector into a USB power adapter 5V@1A.
    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.
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 @5,9:A$`
        i. If you see **GPIB I/O Bus Error – Message 69** the Flash Drive is not plugged in or the Flash Drive is not powered.
    b. `A$`
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 directory that had the file error (substitute that directory name for directory in the command below, and substitute the specific file number for X):
    a. `PRINT @5,9:"directory"`
    b. `FIND @5: X`

```
c. INPUT @5,19:A$
d. A$
```

e. Step d will show the file "header" information for file X in DIRECTORY. If A$ is blank then the file is no longer present. Use the instructions for restoring the Flash Drive from a backup or posted zip file

b. GPIB I/O Bus Error - Message 69

1. If this error occurs after the Flash Drive has been working, try step 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.

c. 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/
   I suggest a Quick Format be 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.

d. 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 7) 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.

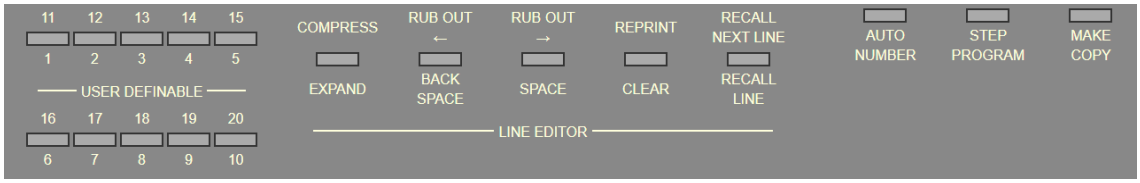

Figure 13- Tektronix 4050 keyboard User Definable and Editing keys

12. Flash Drive NOTES

a. 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. This routine allows you to pick one of the Flash Drive directories to TLIST

b. Flash Drive File Header Description/Comment field

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

c. Flash Drive Directory Names

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

d. 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.

e. 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 is 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.

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

i. An alternate technique is to drag your 4050 ASCII program or DATA file into the Storage pop-up window of the 4051 Emulator fork that supports Flash Drive and Option ROMs located here: https://github.com/Twilight-Logic/Tek405xEmulator
ii. Then edit the new file number and file name fields and save the program into the 4051 emulator. You can then use the Storage Export (pick 4050 Tape Emulator Files) to create a zip of all current

4050 Tape Emulator files and extract your new PROGRAM or DATA file(s) to your desired folder on the microSD card – properly formatted for Flash Drive file header syntax.

iii. The 4051 Emulator will run ALL the Flash Drive programs supported by the 4051 and includes the R05 and R12 Option ROMs.

g. Flash Drive hot-plug power

i. The Flash Drive may be plugged or unplugged from the Tektronix 4050 computer while the 4050 computer is powered on or off.

ii. The Flash Drive USB power cable can be plugged or unplugged from the Flash Drive while the Flash Drive is connected or not connected to the 4050 computer.

iii. It is recommended to unplug the USB power cable from the Flash Drive before removing or inserting the MicroSD card into the Flash Drive.

iv. It is recommended to unplug the Flash Drive from the 4050 computer before removing or inserting the MicroSD card into the Flash Drive.

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

i. Not supported.

13. 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.

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/blob/master/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 169 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$
160 PRINT @5,9:D$
170 FIND @5:1
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 160 changes the director to the Favorite Directory
Line 170 opens file 1 in the Favorite Directory
Line 180 loads the program in file 1 and automatically RUNs that program

Flash Drive AUTO LOAD to Favorite Directory 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.

It would be easy to change the AUTO LOAD logic in the ROOT MAIN MENU to add a file number (other than 1) to run in the Favorite Directory by writing the file number selected in the MAIN MENU in addition to the directory containing that file in ROOT file 120 and changing the RTC Auto Load program in every directory to INPUT not only the Favorite Directory but also the file number to AUTO LOAD.

14. 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/