4D SYSTEMS
TURNING TECHNOLOGY INTO ART

Primary Displays for Raspberry Pi

DATASHEET

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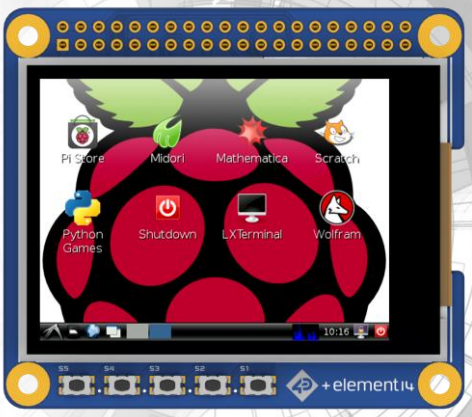

4DPi-24-HAT

Primary Displays for Raspberry Pi

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1. Description

The 4DPi-24-HAT is a 2.4” 320x240 Primary Display HAT for the Raspberry Pi, which plugs directly on top of a Raspberry Pi and displays the primary output which is normally sent to the HDMI or Composite output. It features an integrated Resistive Touch panel, enabling the 4DPi-24-HAT to function with the Raspberry Pi without the need for a mouse.

Communication between the 4DPi-24-HAT and the Raspberry Pi is interfaced with a high speed 48Mhz SPI connection, which utilises an on-board processor for direct command interpretation and SPI communication compression, and features a customised DMA enabled kernel.

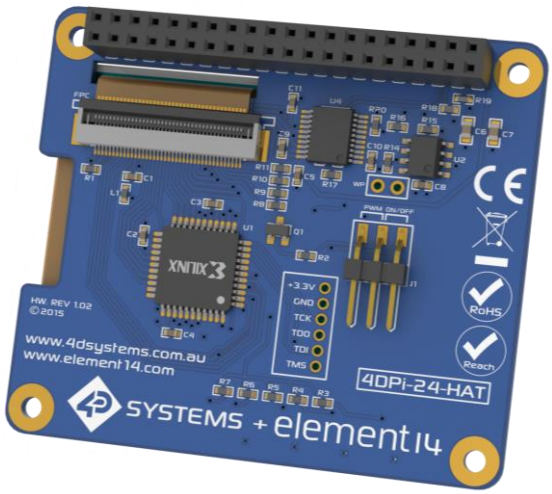
The 4DPi-24-HAT is designed to work with the Raspberry Pi Operating System (previously named Raspbian) running on the Raspberry Pi, as that is the official Raspberry Pi operating system. It is also compatible with Stretch.

The 4DPi-24-HAT is powered directly off the Raspberry Pi's 40-way Header, and the 2.4" Touch Screen allows effortless interaction with the Raspberry Pi Operating System.

Note*: Raspberry Pi is a trademark of the Raspberry Pi Foundation, and all references to the words ‘Raspberry Pi‘ or the use of its logo/marks are strictly in reference to the Raspberry Pi product, and how *this* product is compatible with but is not associated with the Raspberry Pi Foundation in any way.

2. Features

- Universal 2.4” Primary Display for the Raspberry Pi.
- Compatible with Raspberry Pi A+, B+, Pi2, Pi3, Pi3 B+, Pi4, Zero, Zero W and Zero 2 W.
- 240 x 320 QVGA Resolution, RGB 65K true to life colours, TFT Screen with integrated 4-wire Resistive Touch Panel.
- Display full GUI output / primary output, just like a monitor connected to the Raspberry Pi.
- High Speed 48MHz SPI connection to the Raspberry Pi, featuring SPI compression technology.
- Typical frame rate of 25FPS. Higher if image can be compressed by Kernel. Lower if no compression is possible.
- Powered directly off the Raspberry Pi, no external power supply is required.
- On/Off or PWM controlled backlight, selectable by on board jumper.
- On board identification EEPROM.
- Module dimensions: 56.5 x 65 x 14.2mm Weighing ~ 30g.
- Display Viewing Area: 49.0 x 36.7mm.
- 4x mounting holes with 2.6mm diameter for mechanical mounting.
- RoHS and CE Compliant.
- HAT Standard Compliant.



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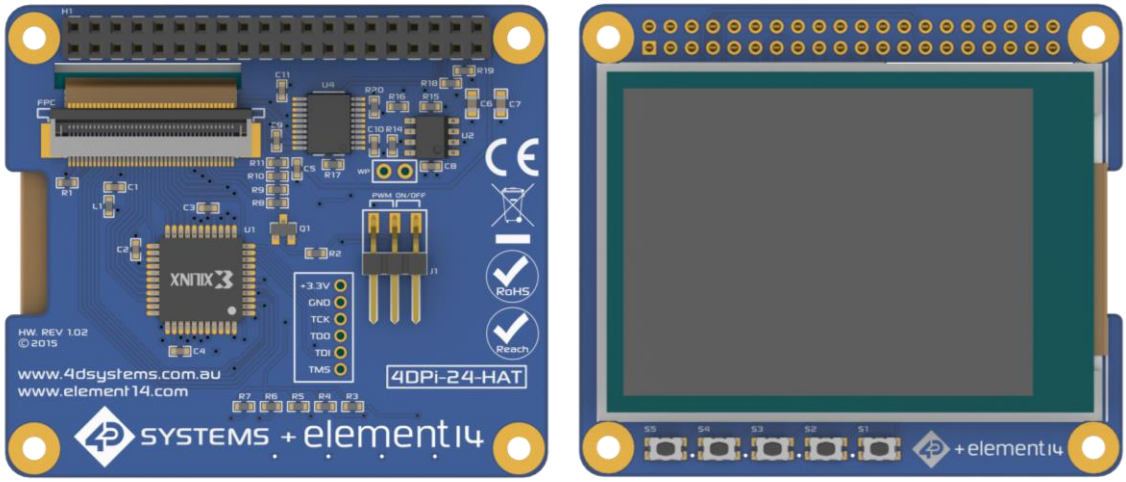
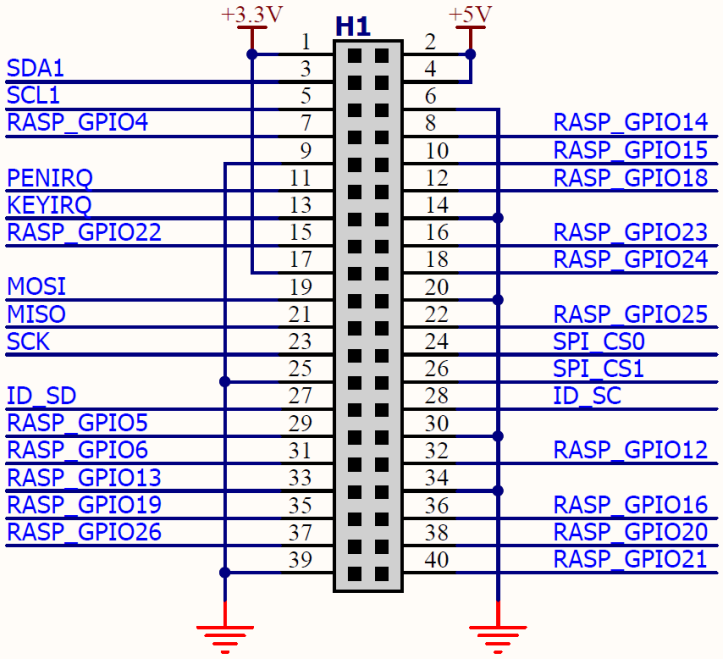
3. Pin Configuration and Summary



RASPBERRY PI HEADER



H1 Pinout (Raspberry Pi Connector on 4DPi-24-HAT-Adaptor) – Female Connetor			
Pin	Symbol	I/O	Description
1	+3.3V	P	+3.3V Supply Pin, connected to the main 3.3V supply of the Raspberry Pi
2	+5V	P	+5V Supply Pin, connected to the main 5V supply of the Raspberry Pi
3	SDA1	I/O	I2C data line - used for touchscreen controller
4	+5V	P	+5V Supply Pin, connected to the main 5V supply of the Raspberry Pi
5	SCL1	O	I2C clock line - used for touchscreen controller
6	GND	P	Ground Pin, connected to the main system Ground of the Raspberry Pi
7	GPIO4	I/O	GPIO on the Raspberry Pi - **unused**
8	GPIO14	I/O	GPIO on the Raspberry Pi - **unused**
9	GND	P	Ground Pin, connected to the main system Ground of the Raspberry Pi
10	GPIO15	I/O	GPIO on the Raspberry Pi - **unused**
11	PENIRQ	I	Interrupt for the touchscreen controller
12	GPIO18	I/O	GPIO on the Raspberry Pi - **unused**
13	KEYIRQ	I	Interrupt for the push buttons
14	GND	P	Ground Pin, connected to the main system Ground of the Raspberry Pi
15	GPIO22	I/O	GPIO on the Raspberry PI – Can be used for PWM Backlight (J1), else **unused**
16	GPIO23	I/O	GPIO on the Raspberry Pi - **unused**
17	+3.3V	P	+3.3V Supply Pin, connected to the main 3.3V supply of the Raspberry Pi
18	GPIO24	I/O	GPIO on the Raspberry Pi - **unused**
19	MOSI	O	MOSI Pin for the SPI
20	GND	P	Ground Pin, connected to the main system Ground of the Raspberry Pi
21	MISO	I	MISO Pin for the SPI
22	GPIO25	I/O	GPIO on the Raspberry Pi - **unused**
23	SCK	O	Clock Pin for the SPI
24	SPI_CS0	O	SPI - Chip select 4DPi-24-HAT
25	GND	P	Ground Pin, connected to the main system Ground of the Raspberry Pi
26	SPI_CS1	O	Chip Select Pin for the SPI - **unused**
27	ID_SD	I/O	I2C Data - ID EEPROM Interface
28	ID_SC	O	I2C Clock - ID EEPROM Interface
29	GPIO5	I/O	GPIO on the Raspberry Pi - **unused**
30	GND	P	Ground Pin, connected to the main system Ground of the Raspberry Pi
31	GPIO6	I/O	GPIO on the Raspberry Pi - **unused**
32	GPIO12	I/O	GPIO on the Raspberry Pi - **unused**
33	GPIO13	I/O	GPIO on the Raspberry Pi - **unused**
34	GND	P	Ground Pin, connected to the main system Ground of the Raspberry Pi
35	GPIO19	I/O	GPIO on the Raspberry Pi - **unused**
36	GPIO16	I/O	GPIO on the Raspberry Pi - **unused**
37	GPIO26	I/O	GPIO on the Raspberry Pi - **unused**
38	GPIO20	I/O	GPIO on the Raspberry Pi - **unused**
39	GND	P	Ground Pin, connected to the main system Ground of the Raspberry Pi
40	GPIO21	I/O	GPIO on the Raspberry Pi - **unused**

I = Input, O = Output, P = Power

4. Connecting the Display to the Pi

4.1. Hardware Connection

The 4DPi-24-HAT is easily connected to a Raspberry Pi by simply aligning the Female 40 way header with the Raspberry PI's Male 40 way header, and connecting them together – ensuring the alignment is correct and all pins are seated fully and correctly.

NOTE: The 4DPi-24-HAT is supported only by the 40-way header, and therefore pressing on the touch screen may result in the 4DPi-24-HAT moving towards the Raspberry Pi, and therefore the circuitry touching the Raspberry Pi. This could result in damage to either product if a short circuit were to occur. It is therefore highly encouraged to mount the display on the Pi using standoffs (not supplied). Some options are available from places like Mouser.

If development is desired on the bench prior to the mounting of the display, please ensure some sort of support is provided between the 4DPi-24-HAT and the Raspberry Pi so they do not touch inadvertently.

4.2. Software Download/Installation

4D Systems has prepared a custom DMA enabled kernel for use with the Raspberry Pi Operating System (previously named Raspbian OS), which is available for download as a single package. This can be installed over your existing OS installation, or it can be applied over a fresh image. It is **recommended** to apply over a fresh image.

If you are starting from a fresh image, start from Step 1, else skip to step 3 if you already have an OS image and which to apply this kernel to that. Please note, it is impossible for us to know what you have done to your OS, if you are not installing from a fresh image – so if you encounter issues, please try, and use a fresh image to determine any modifications which are conflicting with our kernel release. If you are running an OS with a Kernel version later than our Kernel Pack, you are very likely to encounter problems. Please contact support if you have problems. If you already have a custom Kernel, then applying our Kernel Pack over the top will likely stop your previous modifications from working, you will need to build the kernel from scratch using our Source – link available on our website.

1) Install a fresh operating system as discussed in the Raspberry Pi website. Enable SSH and Wi-Fi as preferred.

   Note 1: If you encounter any issues with the latest version, it is advisable to use the Raspberry Pi OS release with matching kernel version as one of the latest 4DPi packages that you plan to use. If there is a newer version than what we have available, please raise a ticket and we will do our best to generate an update as soon as possible.

   Note 2: At the time of writing, the latest release which is based on Debian Bullseye is not fully compatible with our kernel release. It is advisable to use the latest Legacy version which is based on Debian Buster instead.

2) Connect the 4DPi and insert the uSD card into the Raspberry Pi. You will need network connectivity to proceed with the installation. A monitor, keyboard and mouse are required if not using SSH. SSH can be configured in Step 1. Power on the Raspberry Pi and make sure it is connected to your network.

3) Login to the Raspberry Pi using the standard 'pi' and 'raspberry' credentials or as configured in Step 1. If SSH is not used, open the Terminal app.

4) You are welcome to perform a system update if prompted, but please take note that **if you install a newer kernel than what our Kernel Pack offers, then you could encounter problems.** It is therefore advisable to NOT do a system update, as this could update the Kernel.

5) Typically, on modern versions of the Pi OS, this following step is not required or is done automatically. However, it is here for reference. Expand the file system on downloaded image using raspi-config (submenu Expand Filesystem). After exiting raspi-config a reboot is needed.

```
sudo raspi-config

sudo reboot
```

6) Once rebooted, this is the last opportunity for you to do an apt-get upgrade, as doing this after applying the Kernel Pack will render the 4DPi modifications disabled. Please note that doing an upgrade could change your current Kernel which could make the version installed be newer than the Kernel Pack you are about to install next. The Kernel pack must be applied to a kernel very close (newer Kernel Pack is generally OK) if not identical to the kernel your OS is running, or there will be issues.

   Warning: An upgrade should only be done after making sure that the latest kernel is supported by the latest kernel pack from 4D. Otherwise, installing the 4D kernel pack will downgrade the kernel and problems are almost certain to occur.

7) Log into your Raspberry Pi again, you will need to download and install the Kernel Pack which supports the 4DPi. The following step requires sudo 'root' access.

8) To download and install files, enter the following commands in terminal/shell /SSH to download the kernel from the 4D Systems Server:

```
wget https://4dsystems.com.au/media/downloads/4DPi/All/gen4-hats_5-15-32_32bit.tar.gz -O gen4-hats.tar.gz
```

   Then extract the kernel pack:

```
sudo tar --keep-directory-symlink -xzvf gen4-hats.tar.gz -C /
```

   If you encounter issues running this command, try adding `--no-same-owner`

```
sudo tar --no-same-owner --keep-directory-symlink -xzvf gen4-hats.tar.gz -C /
```

   The package selects the kernel required the Raspberry Pi model used automatically. If you want to check for the kernel packages released by 4D systems, proceed to ***Section: Latest Kernel Versions***

9) Reboot the Raspberry Pi by running the command

```
sudo reboot now
```

10) The desktop should begin to show on the 4DPi once the Raspberry Pi has booted.

11) Doing an apt-get upgrade after the Kernel Pack has been installed, will typically disable the 4DPi, as the modules and Kernel likely would be updated in this process, which would disable the 4DPi modifications. To enable the 4DPi again, be sure to download the latest Kernel Pack from the 4D Website (check this datasheet again if there has been an updated version) and perform the same steps and you should get up and running again. Your results may vary, and its always advisable to apply the 4DPi Kernel Pack to a fresh image, but this is not always possible.

12) ADVANCED USERS: If you need to make custom modifications to your Kernel, and want the 4DPi to function also, you will need to build the Kernel from source, and include the 4DPi files in the process. The link to our source is on our website, along with steps required to add in the 4DPi files so this can be enabled in menuconfig while building the Kernel.

4.3. Calibrating the Touch Screen

Each gen4-4DPi which is shipped from the 4D Systems factory is slightly different, in the sense that each of the touch screens has a slightly different calibration. To get the best from your gen4-4DPi, you will need to calibrate the display, so it is as accurate as possible.

To calibrate the touch screen, the xinput_calibrator is required, and the following steps should be carried out. Make sure the Desktop is not running before you start, quit desktop if it is and return to the terminal prompt. Please note that only resistive touch display modules could be calibrated.

1) Install xinput_calibrator (if not installed by default) by running this from terminal:

```
sudo apt-get install xinput-calibrator
```

2) Install the event device input driver:

```
sudo apt-get install xserver-xorg-input-evdev
```

3) Rename 10-evdev.conf file to 45-evdev.conf.

```
sudo mv /usr/share/X11/xorg.conf.d/10-evdev.conf /usr/share/X11/xorg.conf.d/45-evdev.conf
```

4) Check if evdev.conf has a higher number than libinput.conf.

```
ls /usr/share/X11/xorg.conf.d/
```

The user should get something like this:

```
10-quirks.conf     40-libinput.conf     45-evdev.conf 99-fbturbo.conf
```

5) Perform a reboot

```
sudo reboot now
```

6) Reconnect to SSH and run xinput calibrator.

```
DISPLAY=:0.0 xinput_calibrator
```

Perform the calibration and copy results. The result should be something like this:

```
Section "InputClass"
  Identifier     "calibration"
  MatchProduct   "AR1020 Touchscreen"
    Option "Calibration"  "98 4001 175 3840"
  Option   "SwapAxes"  "0"
EndSection
```

7) You may test the changes after xinput calibrator ends. To make the changes permanent, paste the results to **/etc/X11/xorg.conf.d/99-calibration.conf**

```
sudo nano /etc/X11/xorg.conf.d/99-calibration.conf
```

8) Save the file and perform a reboot

```
sudo reboot now
```

The Display should now be calibrated.

4.4. Change the Display Orientation

To change the display orientation, simply edit the /boot/cmdline.txt file

Add the parameter below after the console parts in the parameter list:

```
4d_hats.rotate = 90
```

And change this to have the value of 0, 90, 180 or 270. It should look something like:

```
console=serial0,115200 console=tty1 4d_hats.rotate=90 root= (etc etc)
```

Save the file and restart your Raspberry Pi.

The touch screen will automatically remap the alignment thanks to the custom kernel.

After changing the Display Orientation, you need to calibrate again the screen.

4.5. SPI Frequency and Compression

The gen4-4DPi can be adjusted to work with a range of SPI Frequencies and levels of compression, depending on the requirements of the product/project.

Increasing the frequency can result in a higher Frame Rate (FPS), however will use more power and processor time. Increasing the level of the compression can also result in a higher FPS but may cause the display to corrupt. By default, a SPI Frequency of 48Mhz is used, with a Compression level of 7.

The following parameters are the defaults in the /boot/cmdline.txt file and can be edited to adjust the Frequency and Compression level.

```
4d_hats.sclk=48000000
4d_hats.compress=7
```

Setting compress to be 1 will enable the kernel to control the level of compression based on the frequency selected. This however is not guaranteed to have a good result and may require manually setting the compression level if corruption on the display is experienced.

If corruption or display anomalies occur at any given compression level, try to lower it by 1 value and check if this has improved.

Note, changing the frequency and compression require a restart of the Raspberry Pi.

4.6. Backlight Control

The backlight is controllable in two possible ways. One is using simple on/off control, which is done by sending a GPIO command to the on-board processor, which then turns the backlight on and off. The other is using a DMA-PWM output from the Raspberry PI and controlling the backlight brightness.

The control of the backlight is selected using the Jumper J1, selecting ON/OFF or DMA control. For the simple ON/OFF control GPIO18 is used.

The backlight brightness can be controlled from the terminal, or from a bash script.

Executing the following command will control the backlight.

To turn the backlight OFF:

```
sudo sh -c 'echo 0 > /sys/class/backlight/4d
-hats/brightness'
```

To turn the backlight ON:

```
sudo sh -c 'echo 1 > /sys/class/backlight/4d
-hats/brightness'
```

To control the backlight using DMA-PWM, ensure that the Jumper J1 is on PWM.

The following command can be used to set the backlight from 0 to 100%.

```
sudo sh -c 'echo 31 > /sys/class/backlight/4
d-hats/brightness'
```

The above will set the backlight to 100%. Simply change the ‘echo 31’ to be anything from 0 to 31.

4.7. Parameters Listing

The following is a list of all the custom parameters used by the gen4-4DPi.

rotate: Screen rotation 0/90/180/270 (int)
compress: SPI compression 0/1/2/3/4/5/6/7 (int)
sclk: SPI clock frequency (long)

Valid SPI Frequency values (4d-hats.sclk):
Values can be almost anything. This has been tested up to 64Mhz. Common values would include 64000000 (64MHz), 48000000 (Default), 32000000, 24000000 etc.

Valid Compression values (4d-hats.compress):
0 (compression off)
1 (compression on, auto set based on sclk value)
2 (lowest), 3, 4, 5, 6, 7 (highest compression)

These parameters can be set or read from the /boot/cmdline.txt file, and they can be read from the /sys/module/4d_hats/parameters/ directory.

For example:

```
cat /sys/module/4d_hats/parameters/rotate
```

Will display the current rotation saved.

4.8. HDMI or 4DPi Output

To switch the X Windows output being displayed on 4DPi or HDMI output, X can be launched using either of the following commands:

```
startx -- -layout TFT

startx -- -layout HDMI
```

Alternatively, these commands do the same thing:

```
FRAMEBUFFER=/dev/fb1 startx

startx
```

4.9. DPI Adjustment

It is possible to change the DPI output of the 4DPi the same way as other LXDE based systems.

login as pi and open terminal

Check the current DPI settings by

```
xrdb -query -all
```

The current dpi is listed next to the `xft.dpi` listing.

To change the DPI, it can be done like this. Edit the following file, and then merge it:

```
nano ~/.Xresources
```

Add this line:
Xft.dpi: 75

This will set the DPI to be 75

Save and exit the file.

Merge it so the value gets used, by doing the following:

```
xrdb -merge ~/.Xresources
```

Check again by doing the query.

```
xrdb -query -all
```

Reboot the Pi, and your changes should take effect.

Changing the DPI can make the screen blurry, so take care when adjusting these values. If you get to a point where it is unreadable, SSH into your Pi and change the value back to something reasonable.

Ideally DPI is set based on your resolution, however for small resolution displays, it can be desirable to make the DPI smaller so you can fit more on the screen.

5. Display Module Part Numbers

The following is a breakdown on the part numbers and what they mean.

Example:
4DPi-24-HAT

4DPi - Display Family
24 - Display size (2.4")
HAT - Hardware attached on top.

6. Latest Kernel Versions

Here is the list of the kernel patches released by 4D systems.

Latest releases:
gen4-hats_5-10-103.tar.gz
gen4-hats_5-15-32_32bit.tar.gz (see note 2)

Previous releases:
gen4-hats_5-10-76-4DPi.tar.gz
gen4-hats_5-10-63.tar.gz
gen4-hats_5-4-68.tar.gz
gen4-hats_4-19-57-v7l+_v1.0.tar.gz
gen4-hats_4-14-34_v1.1.tar.gz
gen4-hats_4-9-80_v1.1.tar.gz
gen4-hats_4-9-59_v1.2.tar.gz

Note: (1) It is highly advisable to use a Raspberry Pi OS release with **matching kernel version** (first 2 numbers, and 3rd number needs to be less than or equal) as the Kernel Pack you decide to use. Please refer to section 4.2 point #1 regarding current recommendations.

For example, if your OS uses Kernel 5.4.60, then applying our 5.4.68 Kernel Pack is a good match.

Example 2, If your OS uses 5.4.79, or 5.5.10, then applying 5.4.68 Kernel Pack likely would not be the best idea as it would be a downgrade, and some things may not function correctly.

Note: (2) This kernel package is versions higher than the recommended latest Buster (legacy) version release. This was built to be able to update the Buster version to a matching kernel version of the Bullseye release. To match the kernel, you can use the command: `sudo rpi-update`

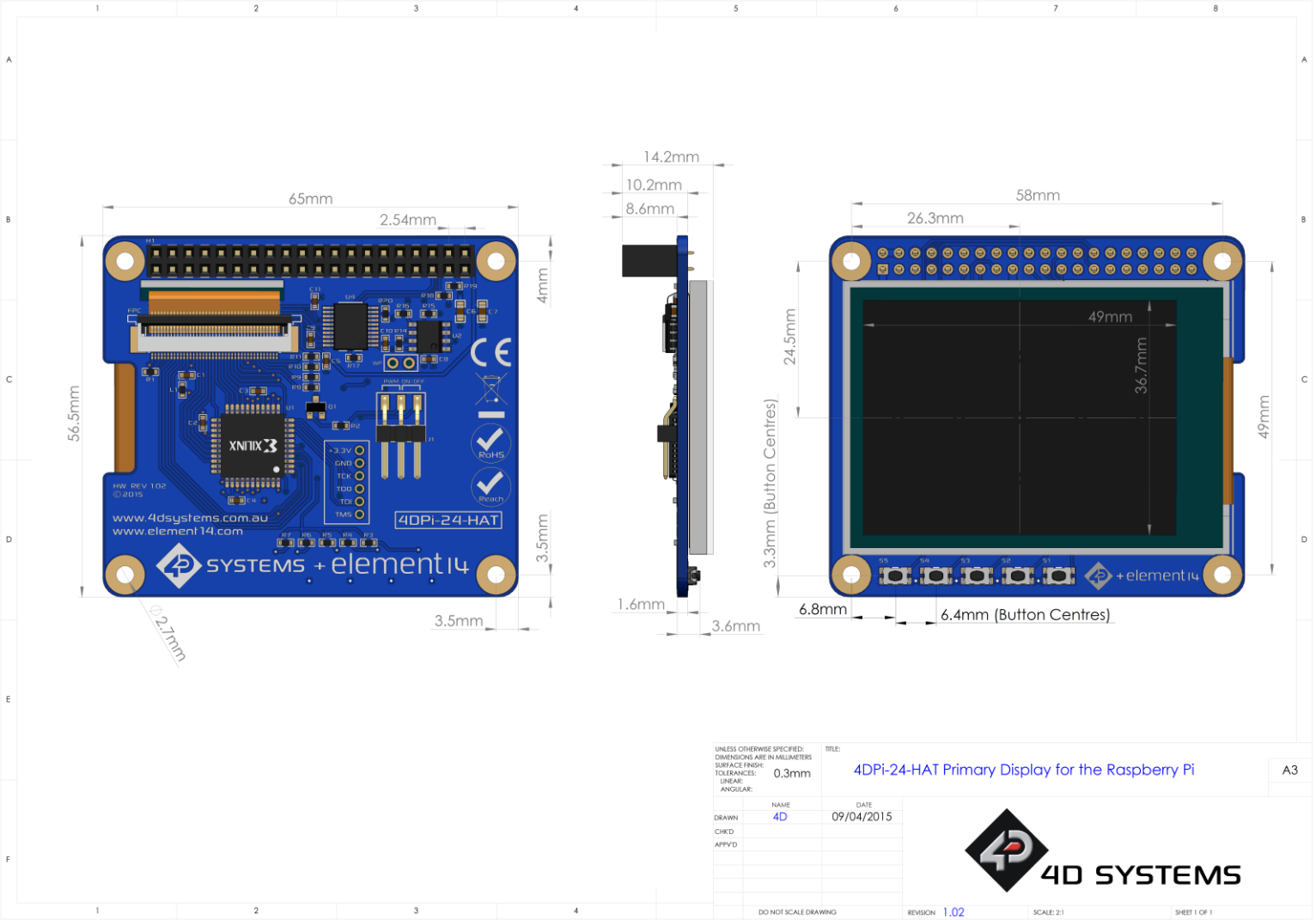
```
sudo rpi-update <git hash>
```

Git hash must be the commit in the Raspberry Pi Firmware Files repository with the same kernel version as the 4DPi package.

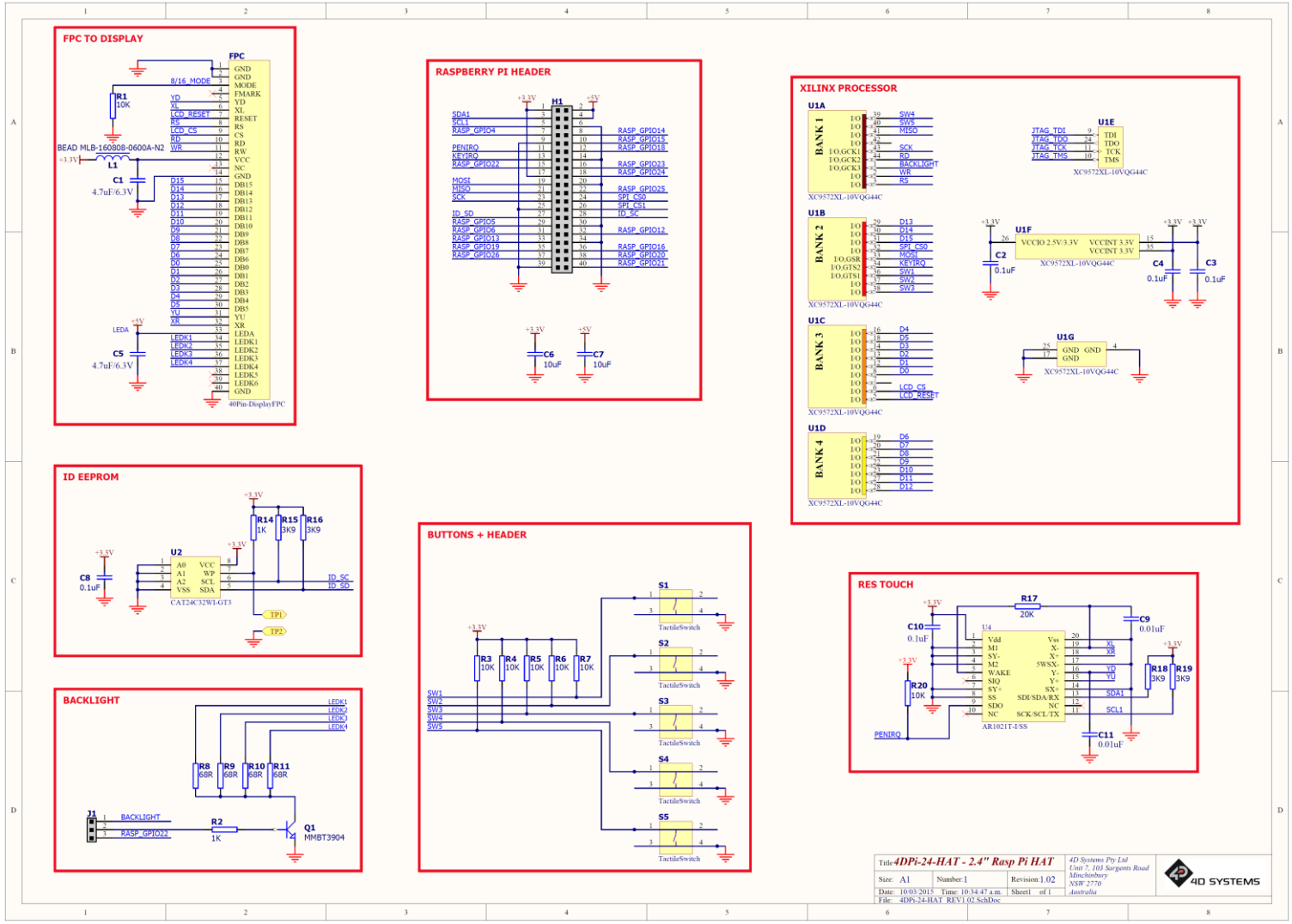
Note: (3) Some older kernel releases may be available upon request. Please contact 4D Systems Support Team for more information:

www.4dsystems.com.au/support

7. Mechanical Details



8. Schematic Diagram



9. Specifications

ABSOLUTE MAXIMUM RATINGS	
Operating ambient temperature	-15°C to +65°C
Storage temperature	-30°C to +70°C

NOTE: Stresses above those listed here may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the recommended operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

RECOMMENDED OPERATING CONDITIONS					
Parameter	Conditions	Min	Typ	Max	Units
Supply Voltage (+3.3V)	Stable external supply required	3.0	3.3	4.0	V
Supply Voltage (+5V)	Stable external supply required	4.5	5.0	5.5	V
Operating Temperature		-10	--	+60	˚C

GLOBAL CHARACTERISTICS BASED ON OPERATING CONDITIONS					
Parameter	Conditions	Min	Typ	Max	Units
Supply Current (ICC)	3.3V Supply.	--	100	--	mA
Backlight Current (ICC)	5V Supply	--	150	--	mA
Display Endurance	Hours of operation, measured to when display is 50% original brightness	--	20000	--	H

PERFORMANCE					
Parameter	Conditions	Min	Typ	Max	Units
Frame Rate (FPS)	Video Playback, Full Screen, 240x320. A higher FPS can be achieved if display outputting lots of blocks of the same colour	--	25	--	FPS

ORDERING INFORMATION
Order Code: 4DPi-24-HAT

10. Appendix 1 – Code Examples – Push Buttons

10.1. Example for communicating to Push Buttons, for C:

```
// test program to read state of buttons on 4D Systems 4DPi displays

#include <stdio.h>
#include <sys/types.h>
#include <fcntl.h>
#include <unistd.h>
#include <string.h>
#include <sys/ioctl.h>

#define LCD4DPI_GET_KEYS _IOR('K', 1, unsigned char *)

void print_keys(int fd)
{
    unsigned char keys;

    if (ioctl(fd, LCD4DPI_GET_KEYS, &keys) == -1)
    {
        perror("_apps ioctl get");
    }
    else
    {
        printf("Keys : %2x\n", keys);
    }
}

int main(int argc, char *argv[])
{
    char *file_name = "/dev/fb1";
    int fd;

    fd = open(file_name, O_RDWR);
    if (fd == -1)
    {
        perror("_apps open");
        return 2;
    }

    print_keys(fd);
    printf("Ioctl Number: (dec)%d  (hex)%x\n", LCD4DPI_GET_KEYS, LCD4DPI_GET_KEYS);

    close (fd);
    return 0;
}
```


Primary Displays for Raspberry Pi

10.2. Example for communicating to Push Buttons, for Python:

```
#!/usr/bin/python
import array, fcntl
from time import sleep
# test program to read state of buttons on 4D Systems 4DPi displays

#LCD4DPI_GET_KEYS = -2147202303

_IOC_NRBITS   =  8
_IOC_TYPEBITS =  8
_IOC_SIZEBITS = 14
_IOC_DIRBITS  =  2
_IOC_DIRMASK    = (1 << _IOC_DIRBITS) - 1
_IOC_NRMASK     = (1 << _IOC_NRBITS) - 1
_IOC_TYPEMASK   = (1 << _IOC_TYPEBITS ) - 1
_IOC_NRSHIFT = 0
_IOC_TYPESHIFT = _IOC_NRSHIFT+_IOC_NRBITS
_IOC_SIZESHIFT = _IOC_TYPESHIFT+_IOC_TYPEBITS
_IOC_DIRSHIFT  = _IOC_SIZESHIFT+_IOC_SIZEBITS
_IOC_NONE = 0
_IOC_WRITE = 1
_IOC_READ = 2

def _IOC(dir, type, nr, size):
#  print 'dirshift {}, typeshift {}, nrshift {}, sizeshift {}'.format(_IOC_DIRSHIFT,
_IOC_TYPESHIFT, _IOC_NRSHIFT, _IOC_SIZESHIFT)
  ioc = (dir << _IOC_DIRSHIFT ) | (type << _IOC_TYPESHIFT ) | (nr << _IOC_NRSHIFT ) |
(size << _IOC_SIZESHIFT)
  if ioc > 2147483647: ioc -= 4294967296
  return ioc
#def _IO(type, nr):
#  return _IOC(_IOC_NONE,  type, nr, 0)
def _IOR(type,nr,size):
  return _IOC(_IOC_READ,  type, nr, size)
#def _IOW(type,nr,size):
#  return _IOC(_IOC_WRITE, type, nr, sizeof(size))

LCD4DPI_GET_KEYS = _IOR(ord('K'), 1, 4)
buf = array.array('h',[0])

print 'Press Top & Bottom buttons simultaneously to exit'

with open('/dev/fb1', 'rw') as fd:

  while True:
    fcntl.ioctl(fd, LCD4DPI_GET_KEYS, buf, 1) # execute ioctl call to read the keys
    keys = buf[0]

    if not keys & 0b00001:
      print "KEY1" ,
    if not keys & 0b00010:
      print "KEY2" ,
    if not keys & 0b00100:
      print "KEY3" ,
    if not keys & 0b01000:
      print "KEY4" ,
    if not keys & 0b10000:
      print "KEY5" ,

    if keys != 0b11111:
      print
    if keys == 0b01110: # exit if top and bottom pressed
      break

    sleep(0.1)
```

10.3. Example for Shutdown and Reset buttons, for C:

```
// test program to Shutdown or Restart Pi using buttons on 4D Systems 4DPi displays

#include <stdio.h>
#include <sys/types.h>
#include <fcntl.h>
#include <unistd.h>
#include <string.h>
#include <sys/ioctl.h>

#define LCD4DPI_GET_KEYS _IOR('K', 1, unsigned char *)

int get_keys(int fd, unsigned char *keys)
{
    if (ioctl(fd, LCD4DPI_GET_KEYS, keys) == -1)
    {
        perror("_apps ioctl get");
   return 1;
    }
    *keys &= 0b11111;
    return 0;
}

int main(int argc, char *argv[])
{
    char *file_name = "/dev/fb1";
    int fd;
    unsigned char key_status;

    fd = open(file_name, O_RDWR);
    if (fd == -1)
    {
        perror("_apps open");
        return 2;
    }

    key_status = 0b11111;
    while(key_status & 0b00001) // press key 1 to exit
    {
        if(get_keys(fd, &key_status) != 0)
             break;

        // printf("key_status: %x\n", key_status);

        if(!(key_status & 0b10000))
        {
            system("sudo shutdown -h now");
            break;
        }

        if(!(key_status & 0b01000))
        {
            system("sudo reboot");
            break;
        }

        sleep(0.1);
    }

    close(fd);
    return 0;
}
```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10.4. Example for Shutdown and Reset buttons, for Python:

```
#!/usr/bin/python
import array, fcntl, os
from time import sleep
# test program to Shutdown or Restart Pi using buttons on 4D Systems 4DPi displays

#LCD4DPI_GET_KEYS = -2147202303

_IOC_NRBITS   =  8
_IOC_TYPEBITS =  8
_IOC_SIZEBITS = 14
_IOC_DIRBITS  =  2

_IOC_DIRMASK    = (1 << _IOC_DIRBITS) - 1
_IOC_NRMASK     = (1 << _IOC_NRBITS) - 1
_IOC_TYPEMASK   = (1 << _IOC_TYPEBITS ) - 1

_IOC_NRSHIFT = 0
_IOC_TYPESHIFT = _IOC_NRSHIFT+_IOC_NRBITS
_IOC_SIZESHIFT = _IOC_TYPESHIFT+_IOC_TYPEBITS
_IOC_DIRSHIFT  = _IOC_SIZESHIFT+_IOC_SIZEBITS

_IOC_NONE = 0
_IOC_WRITE = 1
_IOC_READ = 2

def _IOC(dir, type, nr, size):
#  print 'dirshift {}, typeshift {}, nrshift {}, sizeshift {}'.format(_IOC_DIRSHIFT,
_IOC_TYPESHIFT, _IOC_NRSHIFT, _IOC_SIZESHIFT)
  ioc = (dir << _IOC_DIRSHIFT ) | (type << _IOC_TYPESHIFT ) | (nr << _IOC_NRSHIFT ) |
(size << _IOC_SIZESHIFT)
  if ioc > 2147483647: ioc -= 4294967296
  return ioc
#def _IO(type, nr):
#  return _IOC(_IOC_NONE,  type, nr, 0)
def _IOR(type,nr,size):
  return _IOC(_IOC_READ,  type, nr, size)
#def _IOW(type,nr,size):
#  return _IOC(_IOC_WRITE, type, nr, sizeof(size))

LCD4DPI_GET_KEYS = _IOR(ord('K'), 1, 4)
#print 'ssd {} {:12} {:0>8x} {:0>32b}'.format(ssd1289, hex(ssd1289), ssd1289, ssd1289)
buf = array.array('h',[0])

with open('/dev/fb1', 'rw') as fd:

  while True:
    fcntl.ioctl(fd, LCD4DPI_GET_KEYS, buf, 1) # execute ioctl call to read the keys
    keys = buf[0]

    if not keys & 0b00001:
      break

    if not keys & 0b10000:
      os.system("sudo shutdown -h now")
      break

    if not keys & 0b01000:
      os.system("sudo reboot")
      break;

    sleep(0.1)
```

11. Hardware Revision History

Revision Number	Date	Description
1.02	10/03/2015	Initial Public Release Version

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12. Document Revision History

Revision Number	Date	Description
1.0	08/05/2015	Initial Public Release Version
1.1	17/07/2015	Update of 4d kernel image and cosmetic changes on the datasheet
1.2	24/07/2015	Update of 4d kernel image and cosmetic changes on the datasheet
1.3	16/10/2015	Update of 4d kernel image and cosmetic changes on the datasheet
1.4	10/03/2016	Update of 4d kernel image and cosmetic changes on the datasheet
1.5	11/04/2016	Update of 4d kernel image and cosmetic changes on the datasheet
1.6	24/05/2016	Update of 4d kernel image and cosmetic changes on the datasheet
1.7	21/10/2016	Update of 4d kernel image and cosmetic changes on the datasheet
1.8	11/01/2017	Update of 4d kernel image and cosmetic changes on the datasheet
1.9	24/03/2017	Update of 4d kernel image and cosmetic changes on the datasheet
1.10	01/08/2017	Update of 4d kernel image and cosmetic changes on the datasheet
1.11	07/03/2018	Update of 4d kernel image and cosmetic changes on the datasheet
1.12	23/03/2018	Update of 4d kernel image and cosmetic changes on the datasheet
1.14	06/04/2018	Update of 4d kernel image and cosmetic changes on the datasheet
1.15	14/07/2018	Update of 4d kernel image and cosmetic changes on the datasheet
1.16	13/03/2019	cosmetic changes on the datasheet
1.17	02/08/2019	Update of 4d kernel image, cosmetic changes on the datasheet and addition of Section 6– Latest Kernel Versions
1.18	14/04/2020	Update of 4D kernel image and cosmetic change on the datasheet
1.19	08/27/2020	Added notes regarding using matching kernel versions
1.20	28/06/2021	Updated instructions to contain the latest known information
1.21	17/06/2022	Updated latest kernel versions and instructions

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