



# 4D SYSTEMS

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## 4DPi-24-HAT

2.4" Primary Display for the Raspberry Pi

Compatible with A+, B+, Pi2 and Pi3

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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.

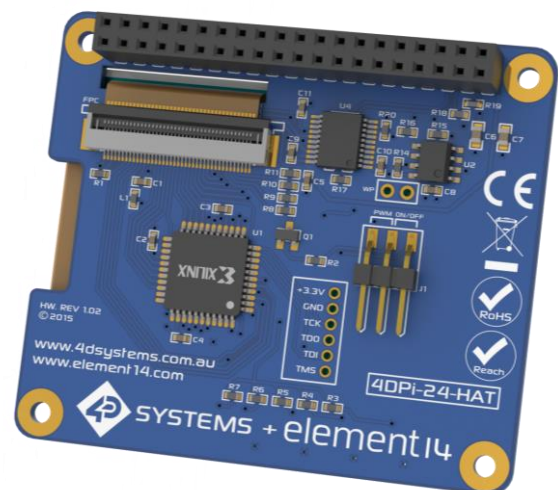
The 4DPi-24-HAT is designed to work with the Raspbian Operating System running on the Raspberry Pi, as that is the official Raspberry Pi operating system.

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 Raspbian Operating System.

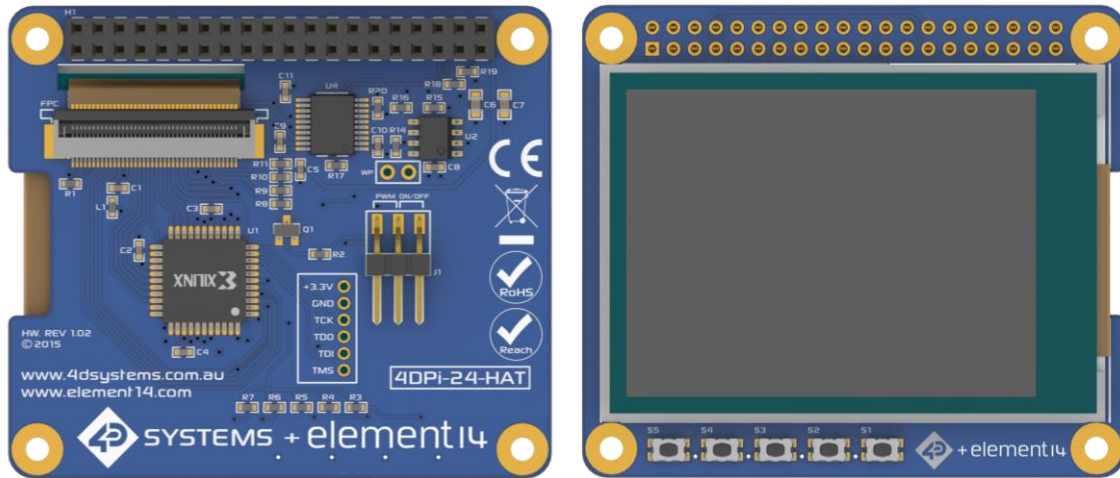
**Note\*:** Raspberry Pi is a trademark of the Raspberry Pi Foundation, and all references to the words 'Raspberry Pi' or the use of its logo/marks are strictly in reference to the Raspberry Pi product, and how *this* product is compatible with but is not associated with the Raspberry Pi Foundation in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

## 2. Features

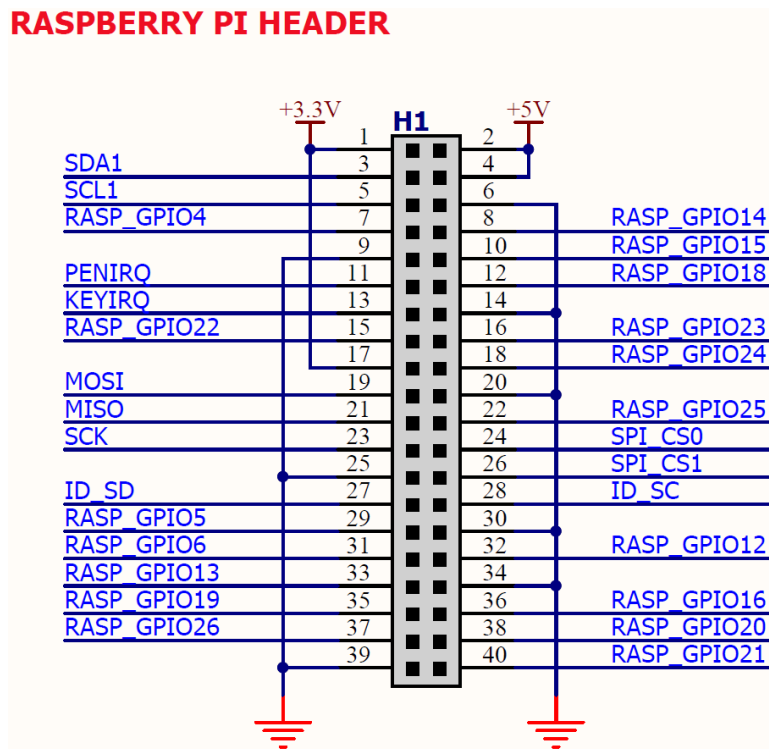
- Universal 2.4" Primary Display for the Raspberry Pi.
- Compatible with Raspberry Pi A+, B+, Pi2 and Pi3.
- 240x320 QVGA Resolution, RGB 65K true to life colours, TFT Screen with integrated 4-wire Resistive Touch Panel.
- Display full GUI output / primary output, just like a monitor connected to the Raspberry Pi.
- High Speed 48MHz SPI connection to the Raspberry Pi, featuring SPI compression technology.
- Typical frame rate of 25FPS. Higher if image is able to 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.



3. Pin Configuration and Summary



**RASPBERRY PI HEADER**



H1 Pinout (Raspberry Pi Connector – FEMALE connector)			
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 - <b>unused</b>
8	GPIO14	I/O	GPIO on the Raspberry Pi - <b>unused</b>
9	GND	P	Ground Pin, connected to the main system Ground of the Raspberry Pi
10	GPIO15	I/O	GPIO on the Raspberry Pi - <b>unused</b>
11	PENIRQ	I	Interrupt for the touchscreen controller
12	GPIO18	I/O	GPIO on the Raspberry Pi - <b>unused</b>
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 <b>unused</b>
16	GPIO23	I/O	GPIO on the Raspberry Pi - <b>unused</b>
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 - <b>unused</b>
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 - <b>unused</b>
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 - <b>unused</b>
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 - <b>unused</b>
30	GND	P	Ground Pin, connected to the main system Ground of the Raspberry Pi
31	GPIO6	I/O	GPIO on the Raspberry Pi - <b>unused</b>
32	GPIO12	I/O	GPIO on the Raspberry Pi - <b>unused</b>
33	GPIO13	I/O	GPIO on the Raspberry Pi - <b>unused</b>
34	GND	P	Ground Pin, connected to the main system Ground of the Raspberry Pi
35	GPIO19	I/O	GPIO on the Raspberry Pi - <b>unused</b>
36	GPIO16	I/O	GPIO on the Raspberry Pi - <b>unused</b>
37	GPIO26	I/O	GPIO on the Raspberry Pi - <b>unused</b>
38	GPIO20	I/O	GPIO on the Raspberry Pi - <b>unused</b>
39	GND	P	Ground Pin, connected to the main system Ground of the Raspberry Pi
40	GPIO21	I/O	GPIO on the Raspberry Pi - <b>unused</b>

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 Raspbian Operating System, which is available for download as a single Package. This can be installed over your existing Raspbian installation, or it can be applied over a fresh image.

If you are starting from scratch, start from Step 1, else skip to step 3 if you already have a Raspbian Image and which to apply this kernel to that. Please note, it is impossible for us to know what you have done to your Raspbian image, if you are

not installing from scratch – so if you encounter issues, please try and use a fresh image to determine if possible modifications are conflicting with our kernel release.

- 1) Download the latest Raspbian Image from the Raspberry Pi website (Wheezy or Jessie): [http://downloads.raspberrypi.org/raspbian\\_la\\_test](http://downloads.raspberrypi.org/raspbian_la_test)
- 2) Load the Raspberry Pi image onto a SD card, using the instructions provided on the Raspberry Pi website for Linux, Mac or PC: <http://www.raspberrypi.org/documentation/installation/installing-images/README.md>
- 3) Insert the SD card into the Raspberry Pi. Do not connect the 4DPi-24-HAT yet. You will need an external monitor / keyboard / network connection, else simply a network connection to the Pi and the rest can be done over an SSH connection. Start up the Pi with at minimum an Ethernet connection connected.
- 4) Either log into the Raspberry Pi from your keyboard/monitor using the standard 'pi' and 'raspberrypi' credentials, else SSH into your raspberrypi and log in via your SSH session.
- 5) 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, It is highly recommended to do an apt-get update and apt-get upgrade to ensure you are running the latest version of the kernel and firmware on your Pi, before you patch it for the 4DPi. Especially if you are using Wheezy. After doing this, reboot once again.
- 7) Once rebooted, log into your Raspberry Pi again, you will need to download and install the kernel which supports the 4DPi-24-HAT. 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
http://www.4dsystems.com.au/downloads/4DPi/All/4d-hats_4-4-9_v1.0.tar.gz
```

```
$sudo tar -xzvf 4d-hats_4-4-9_v1.0.tar.gz -C /
```

By default the package is configured for Raspberry Pi2. To use the kernel on Raspberry Pi1, modify the content of /boot/config.txt.

```
$sudo nano /boot/config.txt
Find and modify the following line:
kernel=kernel7_hat.img
```

change to:

```
kernel=kernel_hat.img
```

Save the changes made to /boot/config.txt.

- 9) On newer Raspbian images, by default the system boots to Desktop GUI. Booting to command line can be selected using the raspi-config tool, submenu Boot Options.

```
$sudo raspi-config
```

- 10) Shutdown the Raspberry Pi safely, and remove the power after it has completed its shutdown. For shutting down use the following command

```
$sudo poweroff
OR
$sudo halt
```

Shutdown can take a while, since many files have to be written from cache to SD card.

- 11) Connect the 4DPi-24-HAT to the Raspberry Pi, and reapply power. The terminal should begin to show on the 4DPi-24-HAT, and will be ready to use once the Raspberry Pi has booted.

### 4.3. Calibrating the Touch Screen

Each 4DPi-24-HAT 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. In order to get the best from your 4DPi-24-HAT, you will need to calibrate the display so it is as accurate as possible.

To calibrate the touch screen for the LXDE GUI, the xinput\_calibrator is required and the following steps should be carried out. Make sure LXDE is not running before you start, quite LXDE if it is and return to the terminal prompt.

- 1) Delete the old calibration file, in preparation for the new one. Do this BEFORE running startx and the calibrator.

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

- 2) This step is to be performed via a SSH session to your Raspberry Pi. If you wish to do this directly with a keyboard on the Raspberry Pi instead, skip to the next step. Enter the following two commands:

```
FRAMEBUFFER=/dev/fb1 startx &
DISPLAY=:0.0 xinput_calibrator
```

- 3) This step is instead of step 2, if you are using a keyboard connected to your Pi. Start the LXDE GUI using the following command:

```
FRAMEBUFFER=/dev/fb1 startx
```

- 4) Execute the xinput\_calibrator command from the terminal after the LXDE GUI has started.

- 5) Follow the directions on the screen. Once complete you should get an output which contains information such as this:

```
Section "InputClass"
    Identifier      "calibration"
    MatchProduct   "ads7846"
    Option         "Calibration"    "119
3736 3850 174"
    # Option      "SwapAxes"        "1"
EndSection
```

- 6) If the /etc/X11/xorg.conf.d directory does not exist, it needs to be created manually.

```
mkdir /etc/X11/xorg.conf.d
```

- 7) Run the following command

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

Copy the information shown in step 4 into this file, save it and exit nano.

- 8) Restart your Raspberry Pi. You should now have a perfectly calibrated 4DPi-24-HAT .

### 4.4. Change the Display Orientation

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

Find the parameter:

```
4dpi.rotate = 0
```

And change this to have the value of 0, 90, 180 or 270.

Save the file and restart your Raspberry Pi.

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

#### 4.5. Change the SPI Freq and Compression

The 4DPi-24-HAT can be adjusted to work with a range of SPI Frequencies and levels of compression, depending on the requirements of the end 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.

```
4dpi.sclk=48000000
```

```
4dpi.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 end 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.

Please refer to Section 4.7 for more information

#### 4.6. Backlight Control

The backlight is controllable in two possible ways. One is using simple on/off control, which is controllable 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, but selecting either ON/OFF or DMA control. For the simple ON/OFF control GPIO22 is used.

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

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

```
echo 80 > /sys/class/backlight/24-hat-pwm/brightness
```

The above will set the backlight to 80%. Simply change the 'echo 80' to be anything from 0 to 100.

To control the backlight using ON/OFF control, ensure the cmdline.txt file has been edited appropriately (and restart the Pi), place the jumper in the ON/OFF position and executing the following commands will control the backlight:

To turn the backlight off:

```
sudo echo 0 > /sys/class/backlight/24-hat/brightness
```

To turn the backlight on:

```
sudo echo 1 > /sys/class/backlight/24-hat/brightness
```

#### 4.7. Parameters Listing

The following is a list of all the custom parameters used by the 4DPi-24-HAT .

**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 (4dpi.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 (4dpi.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/modules/4dpi/parameters directory.



For example:

```
cat /sys/modules/4dpi/parameters/rotate
```

Will display the current rotation saved.

#### 4.8. HDMI or 4DPi Output

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

```
startx -- -layout TFT
```

```
startx -- -layout HDMI
```

Alternatively, these commands do the same thing:

```
FRAMEBUFFER=/dev/fb1 startx
```

```
startx
```

#### 4.9. Changing DPI output

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

```
nano .Xresources
```

Add this line:

```
Xft.dpi: 75
```

reboot... This will set the DPI to be 75

## 5. Notes

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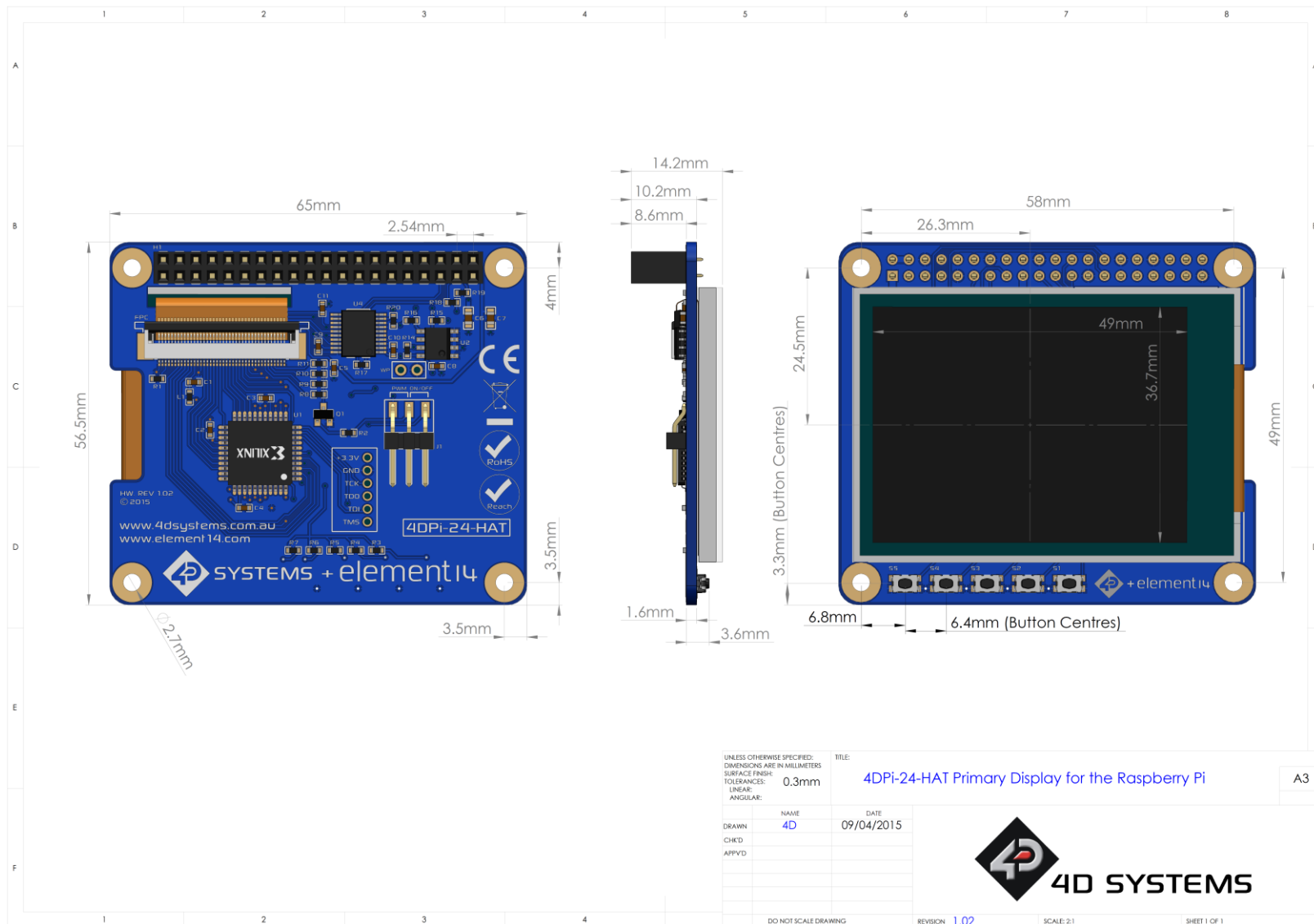
---

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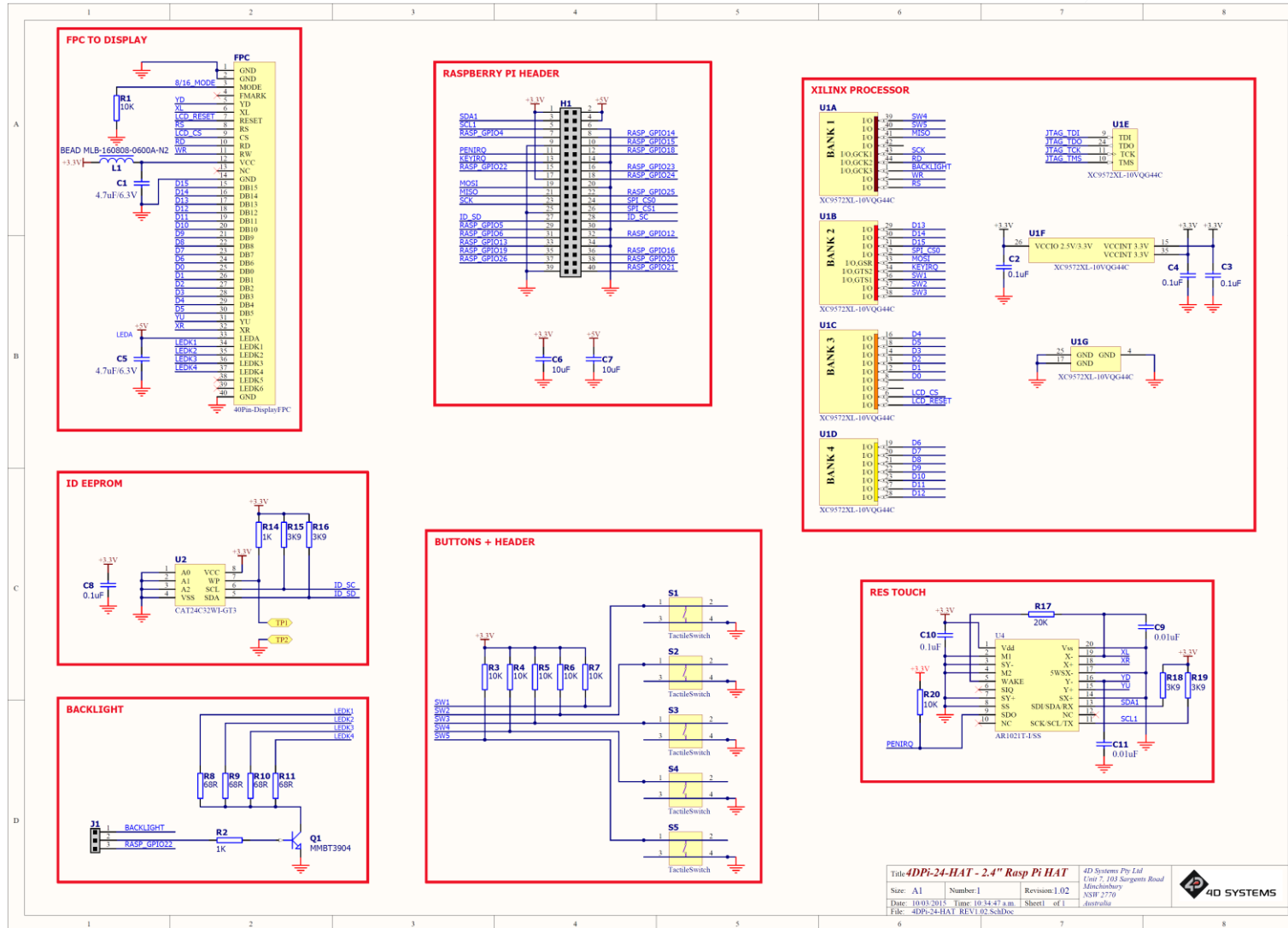
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## 6. Scribble Box

7. Mechanical Details



8. Schematic Diagram



## 9. Specifications and Ratings

### ABSOLUTE MAXIMUM RATINGS

Operating ambient temperature .....	-15°C to +65°C
Storage temperature .....	-30°C +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;
}
```

## 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_TYPMASK   = (1 << _IOC_TYPEBITS) - 1
_IOC_NRSHIFT   = 0
_IOC_TYPSHIFT  = _IOC_NRSHIFT+_IOC_NRBITS
_IOC_SIZESHIFT = _IOC_TYPSHIFT+_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_TYPSHIFT, _IOC_NRSHIFT, _IOC_SIZESHIFT)
    ioc = (dir << _IOC_DIRSHIFT) | (type << _IOC_TYPSHIFT) | (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;
}
```



## 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_TYEMASK = (1 << _IOC_TYPEBITS) - 1

_IOC_NRSHIFT = 0
_IOC_TYRESHIFT = _IOC_NRSHIFT + _IOC_NRBITS
_IOC_SIZESHIFT = _IOC_TYRESHIFT + _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_TYRESHIFT, _IOC_NRSHIFT, _IOC_SIZESHIFT)
ioc = (dir << _IOC_DIRSHIFT) | (type << _IOC_TYRESHIFT) | (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 'ssid {} {:12} {:0>8x} {:0>32b}'.format(ssd1289, hex(ssd1289), ssd1289,
ssid1289)
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)
```

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