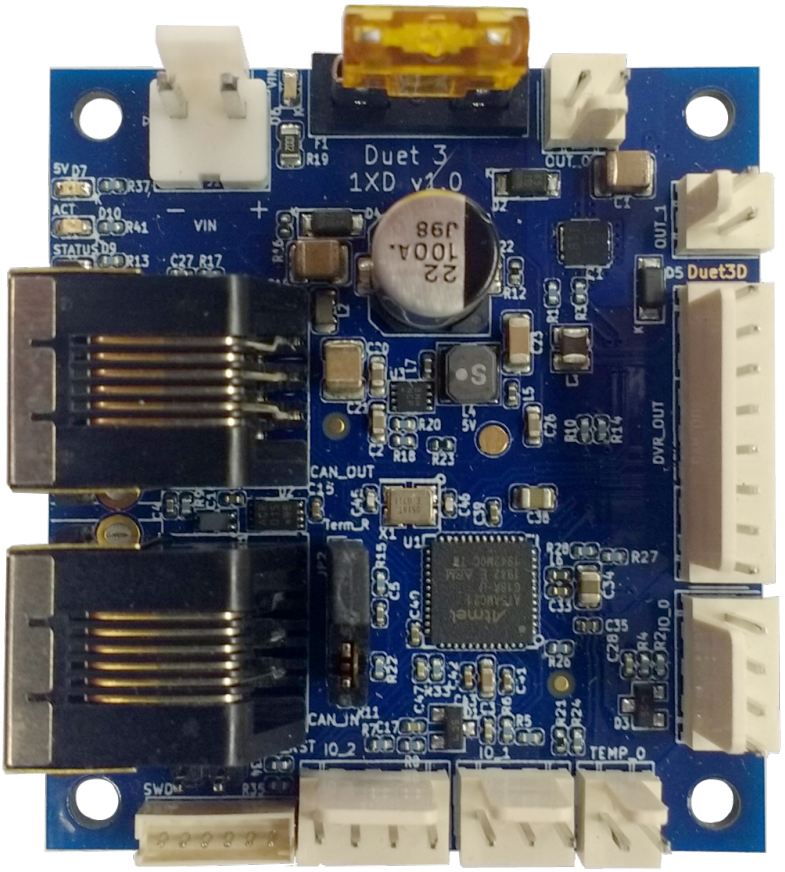
Duet 3 Expansion 1XD

A CAN-FD connected expansion board for the Duet 3 Mainboard that allows connection for a single external stepper driver and associated peripherals.



Introduction

The Duet 3 Expansion 1XD board provides step, direction and enable outputs to interface a Duet 3 system with a motor controller that takes those inputs. In addition it has a number of peripheral inputs and outputs for functions such as sensing driver alarms, temperature and controlling a brake and axis endstop. It connects to the Duet 3 CAN-FD bus using RJ11 connectors (same as the Duet 3 Mainboard 6HC, Duet 3 Mini 5+, Duet 3 Expansion 3HC, and the Duet 3 Tool Distribution Board). Multiple drivers can be daisy chained on the bus, with power (up to 48V) provided locally to the Duet 3 Expansion 1XD board. This allows for very large machines to be constructed without a significant wiring burden and signal integrity issues.

Features

Hardware specification

Processor	ATSAMC21G18A
Processor features	32-bit, 48MHz ARM Cortex M0+, 256KB Flash, 32KB RAM
Networking/Comms	RJ11 CAN In and CAN Out connectors to connect to the Duet 3 CAN-FD bus; serial port
External stepper driver support	1 x 5V differential Step, Dir and Enable output, plus two common +5V pin.
Medium current output	2 x 2A
Temperature inputs	1 x output, optimised for thermistors (reduced accuracy compared to other Duet 3 boards)
Inputs/Outputs	2 x 5V PWM outputs, 3 x digital inputs. Inputs are 30V-tolerant.
Power monitoring	VIN voltage reporting

Operating limits

External stepper driver output	Each pin can source/sink a max of 10mA.
Medium current outputs	OUT0/1 up to 2A each
Input power voltage	12V to 48V
Power input connector rated current	10A maximum, or fused limit (whichever is lower)
Inputs/Outputs	All inputs are 30V-tolerant
Fuses	5A
5V current limit	300mA peak total, 50mA continuous

Firmware notes

- Compatible RepRapFirmware versions: RRF 3.x
- Firmware limitations: See Duet 3 with CAN expansion firmware configuration limitations.

Open source

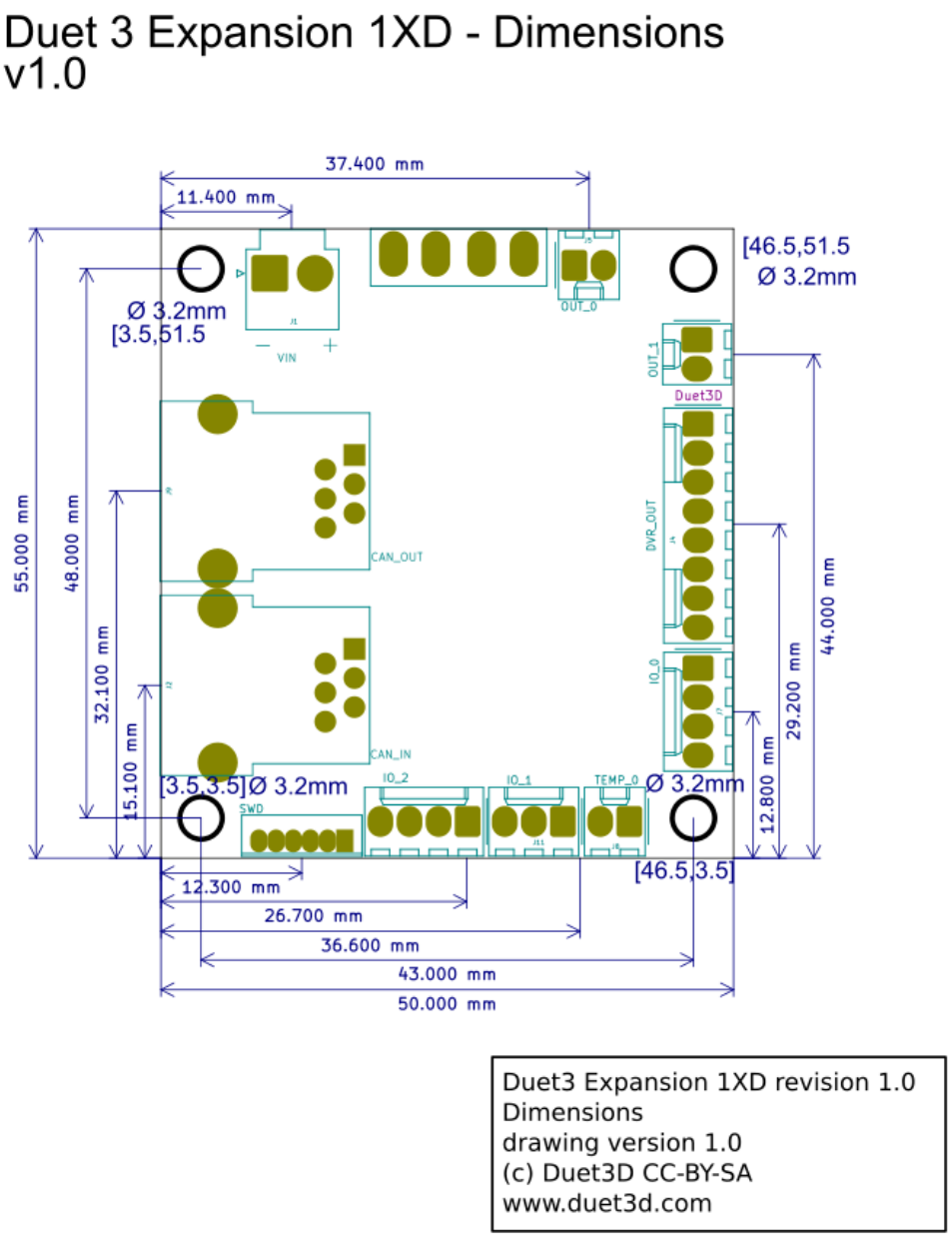
Importantly Duets are Open:

- The Duets are Open Hardware, see our license here .
- All hardware source files are available on Github.

- Both the Duet Web Control web interface and RepRapFirmware are Open Source Software with source files available and actively maintained, see Contributing to development for more information.
- The Duet hardware and RepRapFirmware are built with Open tools: designed in KiCad and Eclipse using open tools means the barrier to getting involved is as low as possible.

Physical properties

Dimensions



3D model

A STEP 3D model of the Duet 3 Expansion 1XD is available on github .

Step rate tests

Step Rates Measured - RRF3.2						
		Step Pulse Timing [a] (µs)				
Motors	**Move Details**	**"fast" [b]**	**1**	**2.5**	**5**	**10**
1 motor	"long" move (50K steps)	83Khz	55kHz	48kHz	40kHz	30kHz
3 motors	Linear Kinematics, per motor, "long" move (50K steps)	70Khz	51Khz	48Khz	40Khz	30Khz
3 Motors	Linear Kinematics, per motor, "short" moves (100x500 steps)	41Khz	44Khz	40Khz	36Khz	27Khz

Notes

[a] The requested pulse timing using M569 Tn:n:n:n . For these tests all the timings were set to the same (e.g. T5:5:5:5). Note in RRF 3.2 the exact pulse produced will be no shorter than this time but may be (slightly) longer due to clock rates and move processing times

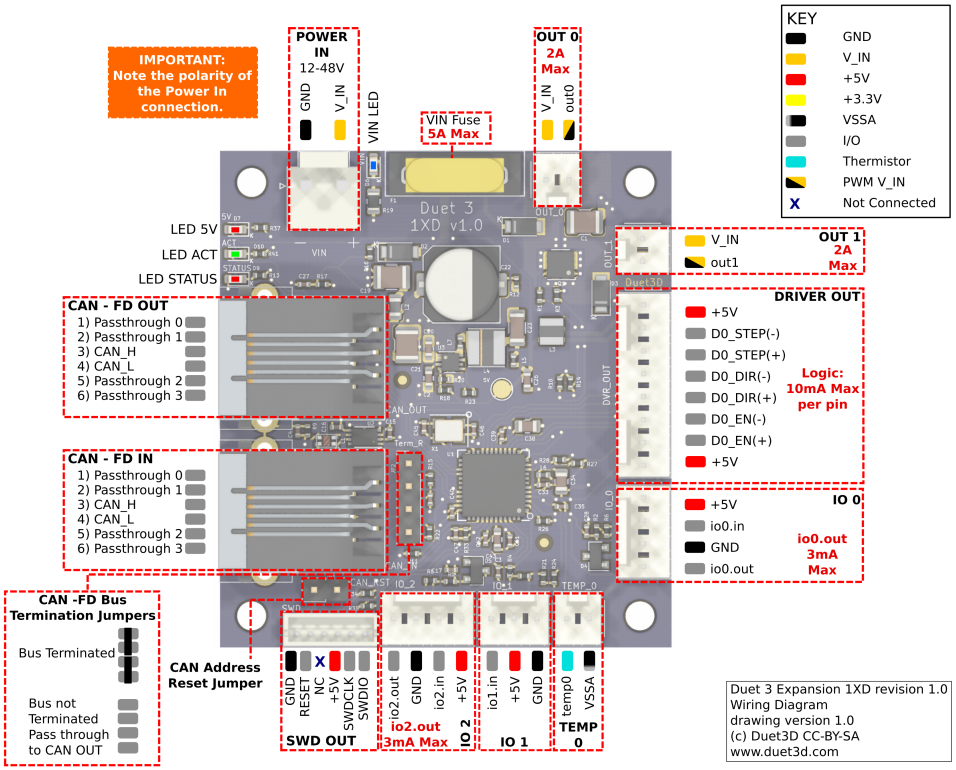
[b] This is setting T0:0:0:0 this allows the firmware to generate short pulses. in measurement these where no shorter than 0.7ns.

The default step pulse timing on the Duet 3 Expansion 1XD is ~2.6µs (equivalent to the T2.5 in the table above). This is because many external stepper and servos drivers require about 2.5µs or longer pulses.

Physical connections

Wiring diagram

Duet 3 Expansion 1XD - Wiring Diagram v1.0



The .svg version of this diagram is available on github .

Description of Connections

Duet 3 Expansion 1XD provides the following connectors:

Header	Label	Function
1 x 2-pin JST VH	POWER IN, VIN, GND	Two pins for main VIN and GND. VIN power is fused at 5A.
1 x 2-pin KK header	OUT_0	Low-current (2A max recommended) output at VIN voltage with PWM capability and built-in flyback diode
1 x 2-pin KK header	OUT_1	
1 x 8-pin KK header	DVR_OUT	5V differential Step, Dir and Enable outputs for a single external stepper driver, plus two common +5V pin. Each pin can source/sink a max of 10mA.
1 x 4-pin KK header	IO_0 IO_2	For low-voltage I/O functions. Inputs for endstops, alarm, brake release etc, output for Alarm reset signal, start built in function (eg homing). Inputs have permanent 27K pullup resistors and will tolerate up to 30V. The outputs are PWM-capable with 5V signal

Header	Label	Function
		levels and 470R series resistors.
		Caution! Check the pinout of these using the wiring diagram linked above before connecting anything to them.
1 x 2-pin KK header	TEMP_0	The "temp0" input is for thermistors but is not as high accuracy as other Duet boards. It is intended for monitoring, for example, the stepper motor temperature, not for serious temperature control. It doesn't have the auto calibration of other Duet 3 boards.
1 x 3-pin KK header	IO_1	Input only, for low-voltage functions. Inputs for endstops, alarm, brake release etc. Input has permanent 27K pullup resistor and will tolerate up to 30V
		Caution! Check the pinout of these using the wiring diagram linked above before connecting anything to them.
1 x 6-pin JST ZH	SWD	This is for firmware debugging and also provides a backup mechanism to program firmware.
1 x 2-pin KK header	CAN_RST	Jumper to force bootloader to request firmware update from Duet 3 main board
1 x 4-pin KK header	TERM_R	CAN bus terminaton. See CAN section below.
2 x RJ11 CAN connectors	CAN_IN CAN_OUT	RJ11 CAN connectors. See CAN section below.

LED indications

LEDs are provided to indicate the following:

Label	Colour	Function
V_FUSED	Blue	Indicates presence of fused VIN power
5V	Red	Indicates presence of 5V power from on-board regulator
ACT	Green	Indicates activity on the CAN-FD bus
STATUS	Red	Status LED. See description below

Status LED: In normal use, the red LED flashes slowly in sync with the main board to indicate that it has CAN sync, or flashes continuously and rapidly to indicate that it doesn't. It also flashes startup error codes, for example if the bootloader doesn't find valid firmware on the board. For a list of these error

codes see CAN_connection basics.

Pin names

For more information on pin names, see Pin Names.

RepRapFirmware 3 uses pin names for user-accessible pins, rather than pin numbers, to communicate with individual pins on the PCB. In RRF 3 no user-accessible pins are defined at startup by default. Pins can be defined for use by a number of gcode commands, eg M574, M558, M950.

The Duet 3 series uses the pin name format "expansion-board-address.pin-name" to identify pins on expansion boards, where *expansion-board-address* is the numeric CAN address of the board. A pin name that does not start with a sequence of decimal digits followed by a period, or that starts with "0." refers to a pin on the Duet 3 Mainboard.

Pin location	RRF3 Pin name	Notes
Outputs		
OUT_0	out0	2A max output
OUT_1	out1	2A max output
Inputs/Outputs		
IO_0	io0.in	30V tolerant
	io0.out	3mA max
IO_1	io1.in	30V tolerant
IO_2	io2.in	30V tolerant
	io2.out	v1.0 and later board. 3mA max
TEMP_0	temp0	

Input/Output

OUT_0 and OUT_1 are PWM-capable, maximum current 2A.

The individual IO_x connectors have the following capabilities:

IO #	UART/I2C?	Analog in?	PWM out?	Notes
0	No	No	Yes	
1	No	Yes	No	Input only, no ouput pin.
2	No	No	Yes	

Note: RepRapFirmware does not currently support I2C on Duet 3 boards.

External Stepper Connection

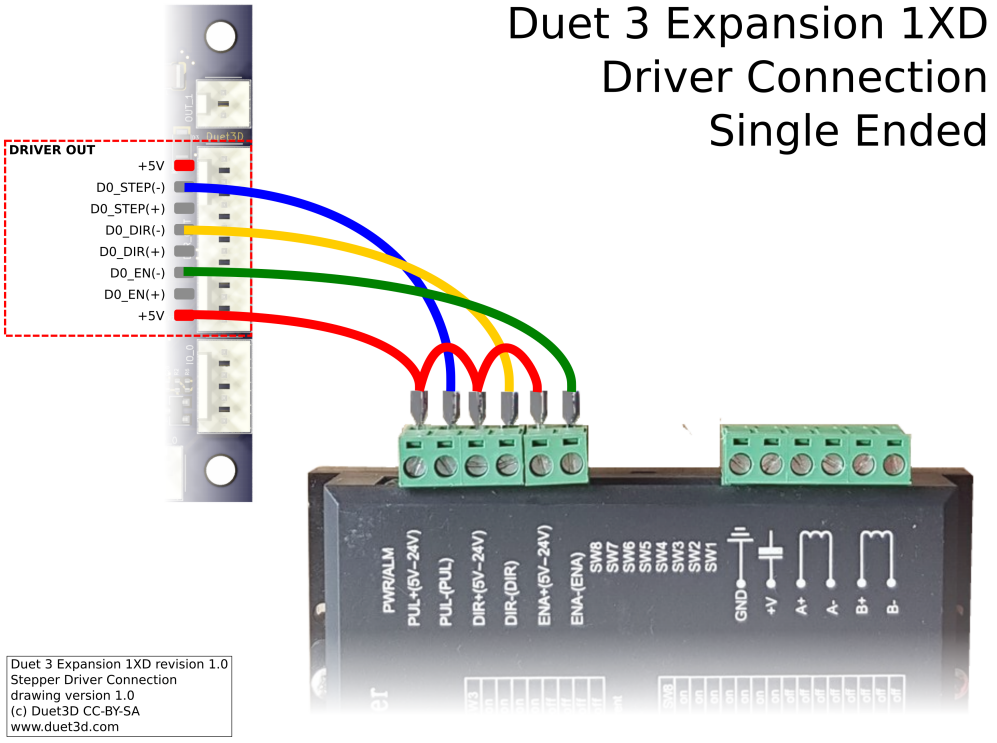
The Duet 3 Expansion 1XD v1.0 offers two methods of connecting to external stepper and servo drivers that accept a 5V step/dir/enable signal. Many drivers will work fine in single ended mode, which requires less wiring. Differential mode should be more resistant to electrical noise. Some drivers will only work with differential mode.

Single Ended Connection | Differential Connection

In this mode the +5V wire from the 5-pin connector on the Duet 3 Expansion 1XD is daisy chained to Step+, Dir+ and Enable+ on the external driver.

Duet 3 Expansion 1XD Pin	Driver Pin
D0_STEP(-)	STEP-*
D0_DIR(-)	DIR-
D0_EN(-)	EN-

**Note on some drivers the Step pin is called the Pulse or PUL pin.*



CAN

See also CAN connection basics.

Connection

Two RJ11 connectors labeled CAN IN and CAN OUT. In fact it doesn't matter which you use for the cable from the main board and which you use for the cable to the next expansion board, because they are wired in parallel.

The STATUS LED indicates CAN bus state. When the expansion board starts up this LED will blink rapidly. If the expansion board is connected to a main board running compatible firmware, the LED on the expansion board will switch to blinking synchronously with the main board LED once time sync has been established across the CAN bus.

Termination

Just behind the RJ11 connectors is a 4-pin terminal block. On the last board in the CAN chain only (the one with a cable in only one of the RJ11 connectors), two jumpers must be fitted in that block to terminate the CAN bus. Jumpers must not be fitted in expansion boards that are not at the end of the CAN bus.

Address

See "Set the CAN address" below.

Power

Supply between 12V and 48V to the 2-pin JST VH VIN power connector on the board, observing the correct polarity.

Commissioning

See also CAN connection basics.

Default configuration

All boards in the system must have different CAN addresses. Duet 3 Expansion 1XD boards are shipped set to a default CAN address of 122. They will also revert to 122 if you use the jumper to force the bootloader to request new firmware. Therefore, if you have more than one new Duet 3 Expansion 1XD board, only one of them must be powered up and connected to the CAN bus. So disconnect power to all but one of them (you can leave the CAN bus connected if it's easier). When you have changed the CAN address of that board, you can connect the next one; and so on.

Startup Time

It is recommended to add the following to config.g, before any commands that reference any CAN bus connected expansion boards

```
G4 S2 ; wait for expansion boards to start
```

Testing communication

Check that you can communicate with the Duet 3 Expansion 1XD board, by sending:

```
M115 B122
```

If that fails try placing a jumper on the CAN_RST pins and powering up, then power down and remove the jumper before powering up again, this will reset the CAN-FD bus settings to the default (address 122, bus speed 1Mbps)

Update the bootloader

Duet 3 expansion boards and tool boards have a bootstrap loader written to the start of flash so that they can load firmware from the main board via CAN. This bootloader may occasionally need to be updated in order to support new features. See Updating the bootloader on Duet 3 expansion and tool boards.

Updating the firmware

The Duet 3 Expansion 1XD board will be shipped with firmware loaded during production. You can check the version loaded by sending

```
M115 B122
```

(or B## where ## is the new CAN address of the board if you have changed it already)

To update the firmware get the latest version from the RepRapFirmware github. It is recommended to upgrade all the firmware in your Duet 3 system together so that the versions do not get out of sync.

Send `M997 B##` to carry out a firmware update, the bootloader will request the Duet3Firmware_EXP1XD.bin from the Duet 3 Mainboard, it needs to be in the /firmware folder (/sys folder for versions of RRF before 3.3).

Set the CAN address

- Send command `M115 B##` to verify that the main board can communicate with the 1XD board, where ## is the default address of 122 if it has not been changed already.
- Send command `M952 B# A##` where ## is the new address you want to use. Allowed CAN addresses for normal use are 1 to 119. We suggest you use addresses starting at 40 for 1XDs. So for the first 1XD board, if your new CAN board was at address 122, send `M952 B122 A40` .
- Power the system down and up again, or send `M999 B122` . This will cause the 1XD board to restart with the new address.
- Send command `M122 B40` (or whatever address you chose) to verify that you can communicate with the 1XD board at its new address
- You can now power up the next 1XD board and commission it in the same way, **choosing a different CAN address for it**.

Configuration examples

CAUTION: before using these examples check the datasheet and user manual of the external driver you are using. Especially: check compatibility of signal voltages and the implication's of triggering actions on the external driver or motors.

External Driver | Alarm | Temperature sensor | Motor Brake Control

The board defaults to the following external driver parameters (note, these may change in future firmware versions):

- ENA output: active to enable drive (M569Pxx R0). If driving the ENA pins of your external driver disables the drive, use R1 in the M569 command for this driver.
- 2.7us minimum step pulse width, step pulse interval, direction-to-step setup time, and direction-to-step hold time (M569 Pxx T2.7:2.7:2.7:2.7). These are satisfactory for some external stepper drivers.

Here's an sample excerpt from a config.g file to drive the X and Y motors from Duet 3 Expansion 1XD boards configured at CAN addresses 40 and 41, driving DM556 or similar drivers:

```
M569 P40.0 S0 R1 ; change enable polarity, active = disable drive
M569 P41.0 S0 R1 ; change enable polarity, active = disable drive
M584 X40.0 Y41.0 ; set X and Y drivers
```

Revisions

Revision v1.1 | Revision v1.0 | Prototype v0.4

This is a minor revision with no changes to functionality or mounting hole positions

- The SWD header may not be populated.
- Additional test points added.
- 5V power indication LED moved to more easily distinguish the CAN STATUS LED (they are both red)
- Additional protection to the temperature measurement circuit