
TAPAS Quick-Start Guide

Use your TAPAS
board with
Raspberry PI and
TI InstaSPIN

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CAUTION

The TAPAS community inverter board is not **a** toy! It is intended for laboratory use only. Never use it in **a** productive environment! (see section 6)

The TAPAS board can get very hot – never touch the board during operation. Always use an appropriate case.

If the TAPAS board is used in conjunction with mechanical, electromagnetic, acoustic, optical or other components, e.g. a motor drive, significant forces can occur. Always ensure safety of the entire set-up! Prevent direct physical contact, always place set-up in an appropriate case, employ safe software techniques (e.g. torque limiting) and limit the supply current.

The device is very sensitive to electrostatic discharge – handle with care! Never touch the board if the supply voltage is turned on!

Foreword and acknowledgements

This board (TAPAS) is intended to train the next generation of power electronics researchers and (application) engineers. It is designed as an educational platform that addresses enthusiasts as well as scholars in university and industry.

TAPAS features a 48V, 3-phase GaN power stage with on-board filters. This design-choice allows for a very high switching frequency/bandwidth (500kHz and beyond) whilst producing a smooth output wave-form. In contrast, commonly available IGBT or MOSFET converter boards typically have a limited bandwidth and/or produce a square output wave-form.

This unique feature of high bandwidth and smooth output makes TAPAS to some degree universal, giving rise to educational applications in AC and DC drives, DC/DC power conversion, audio, robotics, magnetic field control, DC-battery charging, etc. Note that universality is achieved with a single, fixed hardware platform where the overall functionality is defined via software (changes) only – the reason why we coined the term “Software Defined Inverter” (SDI).

TAPAS is Raspberry PI compatible and multiple boards can be used in collaboration, giving rise to many-phase applications such as quadcopters or multi-axis servo control. Together with open-source code examples and extensive documentation we made TAPAS as accessible to the community as possible.

To help us make TAPAS also affordable, we would like to thank our friends and partners at Texas Instruments, Efficient Power Conversion (EPC), Würth Elektronik and Allegro Micro who sponsored most of the active and passive components on the board (see bill of materials). I hope you will have as much fun with TAPAS as we had making it.

Dominic Buchstaller
(Concept and lead-design - TAPAS)



Created by:



Components sponsored by:



<http://www.siemens.com>,

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<http://www.ti.com>, <http://epc-co.com>,

<http://www.we-online.com>

<http://www.allegromicro.com>

1. INTRODUCTION

This quick-start-guide will lead you through the necessary steps to get TAPAS up and running with most commercially available DC-brushless motors.

If you are new to Texas Instrument DSPs or power conversion, we advise you to start with this guide. It will take you through the necessary steps to set-up your (coding) environment and bring the board to life. You are then free to explore the endless possibilities that the platform provides.

TAPAS key characteristics

- DC-Input 12V – 48V
- Maximum DC / AC (per phase) current - 30A
- Up to 300W continuous power - passively cooled (@>120kHz switching frequency)
- Switching frequency up to 600 kHz at reduced load
- On-board output-filter for sinusoidal AC output
- Texas Instruments C2000 Piccolo (TMS320F28069M) DSP - InstaSPIN-enabled
- CAN, GPIO, UART, SPI, 2 x QEP (encoder) interface onboard
- Raspberry-Pi compatible

Box contents

- TAPAS board
- This quick-start guide
- An SDI sticker
- 7 (optional) board-connectors (JP7, JP10, JP11, JP13, JP14, SV3, SV4) for hand-soldering

Required materials

To get started with TAPAS you will need the following (additional) items.

- We highly recommend placing TAPAS in a case. This will keep your TAPAS board safe. The 3D model for our very own case can be found and downloaded here: <https://github.com/SDI-SoftwareDefinedInverter/TAPAS/blob/master/TAPAShousing.zip>

The archive contains multiple files for e.g. the bottom part and the lid of the case. If you don't own a 3D printer, many local 3D printing services are available on-line. Print in ABS.

- DC power supply with minimum 12V and >3A continuous current output. Alternatively, you may use any battery with the correct voltage and an appropriate fuse in the supply line
- A DC brushless motor
- If you want to use TAPAS with Raspberry PI we recommend an Raspberry PI Zero (W)
- If you want to start programming with TAPAS you will need a JTAG programmer. We recommend using the OLIMEX TMS320-JTAG-USB XDS100-V2
- If you want to use the TAPAS platform with a Raspberry Pi, you may also want to fasten the two PCBs together. Then you will need
 - 4 screws M2,5 x 6mm (plastic)
 - 4 screw nuts M2,5 (plastic)
 - 4 spacers M2,5 x 10mm with one male and one female thread (plastic)
 - 12 washers M2,5 (plastic)

2. GETTING STARTED WITH TAPAS AND RASPBERRY PI

- Create an SD-Card image for your Raspberry Pi Zero (W) (<https://www.raspberrypi.org/documentation/installation/installing-images/>)
- Insert SD card in Raspberry Pi Zero (W) and check that the Raspberry PI boots to a command prompt
- Make sure that you have a working Python 3.0 and git installation

```
python --version  
git --version
```

- Get the TAPAS software and documentation package from <https://github.com/SDI-SoftwareDefinedInverter/TAPAS> and place it into your home folder

```
cd  
git clone  
https://github.com/SDI-SoftwareDefinedInverter/TAPAS.git
```

- If successful, halt your Raspberry PI

```
sudo halt
```

- Set the SPI-Address select DIP switch to (OFF)-(ON)-(OFF)-(OFF) for the switch positions from (1) – (4) (see pinout)
- Disconnect the Raspberry PI from any power source and plug it into the TAPAS Raspberry PI board connector (see pinout).
- Connect your TAPAS board to a DC power supply and to a DC brushless motor (see pinout).
- Set the supply voltage to 12V with 3A current limit and turn it on.
- Log into your Raspberry PI and type

```
cd ~/TAPAS  
python3 TAPASstart.py
```

- Then follow the prompts on the monitor.

3. GETTING STARTED WITH TAPAS AND CODE COMPOSER STUDIO

CAUTION

The stock TAPAS firmware implements software features that ensure safe operation. Changing the stock TAPAS firmware may damage or destroy your TAPAS board, lead to harm and/or danger. Make sure that you fully understand the supplied sample code and the underlying principles before flashing your own firmware.

For programming the TAPAS-Board, we recommend Code Composer Studio from Texas Instruments. It is free of charge and can be downloaded from here:

http://processors.wiki.ti.com/index.php/Download_CCS

Choose the correct setup-package for your OS and install it following the instructions in the installation-wizard.

The drivers for the OLIMEX JTAG-Debug probe are included in the standard installation package. If you choose a JTAG Programmer from another vendor – make sure that you installed the correct drivers and that it is compatible with code composer studio.

To be able to use the InstaSpin capabilities of the DSP, you require “motorware” version 1_01_00_16. Install git for your operating system and clone the repository in the same way, you did it for the Raspberry Pi calling

```
git clone  
https://github.com/SDI-SoftwareDefinedInverter/TAPAS.git
```

Motorware is only available as a windows installer executable also included in the previously cloned repository in the file *motorware.zip*.

Alternatively you can download the archive with the windows installer via a browser here: <https://github.com/SDI-SoftwareDefinedInverter/TAPAS/blob/master/motorware.zip>

As the TAPAS board definition is not contained in motorware per default and TAPAS has some additional features, compared to most of the development-kits from TI, some modifications to your motorware installation have to be done before being able to do firmware-development for this platform. These modifications basically include inserting some additional drivers and replacing existing modules, that are for example needed for the external IO of the board.

All the necessary changes to motorware can be done automatically by using our patch-file *SDITAPASmotorwarePatch.patch* included in the previously cloned repository.

If you use git in bash-mode, you have a possibility to run the patch command for changing your motorware-installation under windows.

Copy the file *SDITAPASmotorwarePatch.patch* to the motorware installation folder (usually *c:\ti*), start git in bash mode in this folder and execute the following commands:

```
dos2unix SDITAPASmotorwarePatch.patch
patch -p0 -i SDITAPASmotorwarePatch.patch
```

If this command has finished execution successfully, you can start with the motorware-labs and the quick-start demo firmware. To edit the quick-start project, start Code Composer Studio and choose a workspace location. Close the welcome-window and then select "Project->Import CCS Projects..." In the upcoming window choose the option "Select search-directory" and click the "Browse" – button. Navigate to the directory of your motorware installation, go to the folder

```
<drive>:\ti\motorware\motorware_1_01_00_16\sw\solutions\instaspi  
n_foc\boards\TAPAS_V1_0\f28x\f2806xF\projects\ccs5\
```

and click the "OK" button.

In the “Discovered projects” – list below you will see all the projects lying in the selected directory. Here, you can choose for example the project “*TAPAS_quick_start*”, which represents the demo firmware used with the python – script for the Raspberry PI.

For all the other projects in the folders

```
<drive>:\ti\motorware\motorware_1_01_00_16\sw\solutions\instaspin_foc\boards\TAPAS_V1_0\f28x\f2806xF\projects\ccs5\
```

and

```
<drive>:\ti\motorware\motorware_1_01_00_16\sw\solutions\instaspin_motion\boards\TAPAS_V1_0\f28x\f2806xF\projects\ccs5\
```

please have a look at the “*InstaSPIN Projects and and Labs User’s Guide*” which comes together with the motorware-installation and is located at

```
<drive>:\ti\motorware\motorware_1_01_00_16\docs\labs\instaspin_1abs.pdf
```

with a standard-motorware installation. There you can further find some information how to compile the firmware, start a debugging session, flash the DSP and get an impression, what all the program components actually do. Please keep in mind, that all the labs for driving two motors independent with one DSP are not possible with TAPAS, as there is only one 3-phase power stage.

To be able to run our TAPAS demo-webapp you also require the InstaSPIN-UNIVERSALGUI from Texas Instruments which you can get here:

<http://www.ti.com/tool/INSTASPINUNIVERSALGUI>

You have now completed the installation of the TAPAS development environment. We have created a TAPAS-webapp including not only external IO for you to check if everything is working ok. Download it here:

<https://github.com/SDI-SoftwareDefinedInverter/TAPAS/blob/master/TAPASwebapp.zip>

unzip it and place it in the folder:

```
<drive>:\ti\gui composer\webapps\
```

And now? How do we get it running?

If you plan to do unlock even more features of TAPAS, we recommend installing the Texas Instruments controlSUITE which is available here:

<http://www.ti.com/tool/controlsuite>

It delivers a lot of ready-to-use peripheral-drivers and examples for the C2000DSP series.

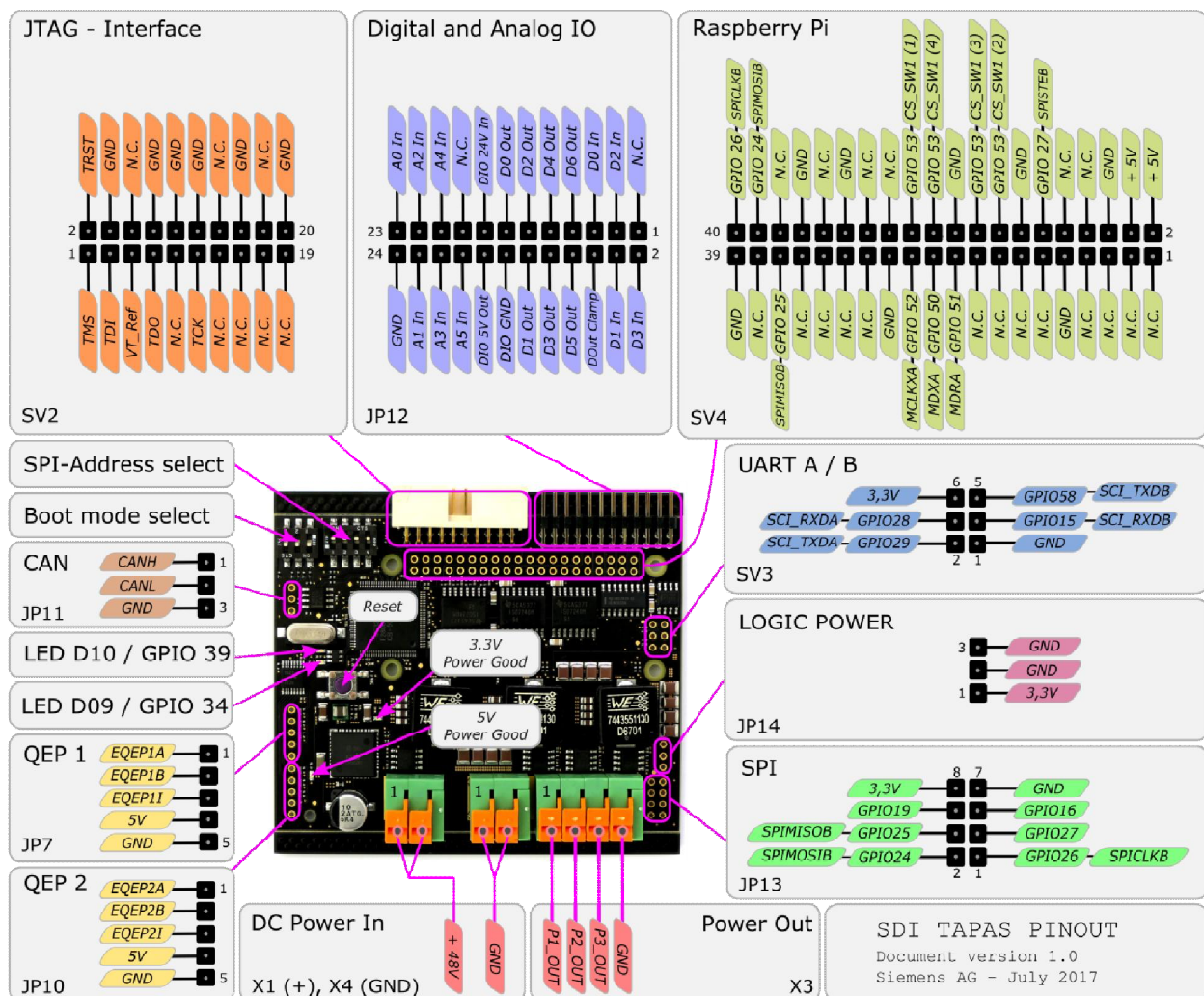


Figure 1: TAPAS pinout

4. FREQUENTLY ASKED QUESTIONS / TROUBLE SHOOTING

Q: Where can I get a TAPAS board

A: You can get one here: <http://xxx>

Q: Can I use other JTAG-Programmers than the OLIMEX?

A: Yes you can. As long as it's 3,3V compatible and supported by Code Composer Studio it should work.

Q: Can I run the board at full power for longer periods of time?

A: Yes you can. In that case it is important to manage the board temperature. We recommend adding some temperature monitoring code (see examples) and dynamically limit the output current. Keep the board temperature below 90° C at all times to keep your TAPAS board healthy.

Q: If I abruptly reduce the speed of my motor – why is the JTAG-connection interrupted or other funny things happen?

A: It is very likely that you are using a DC power supply and not a battery to power TAPAS. The breaking energy is fed back into the DC supply and causes an abrupt rise in DC voltage. Note that although TAPAS is designed to absorb some breaking energy, excessive DC voltage peaks may damage the board. To prevent this effect, limit the rate of change in motor velocity, use a battery instead of a DC power supply or invest in a current sink (breaking chopper).

5. REFERENCES

The following documents can be helpful in developing with TAPAS:

- TAPAS Pinout:
<https://github.com/SDI-SoftwareDefinedInverter/TAPAS/blob/master/TAPAS-Pinout.pdf>
- TAPAS Schematics:
<https://github.com/SDI-SoftwareDefinedInverter/TAPAS/blob/master/TAPAS-Schematic.pdf>
- This 13document (quick start guide):
<https://github.com/SDI-SoftwareDefinedInverter/TAPAS/blob/master/TAPASquickStartGuide.pdf>
- InstaSPIN-FOC and InstaSPIN-MOTION user guide :
www.ti.com/lit/ug/spruhj1g/spruhj1g.pdf
- Instaspin projects and labs user's guide
-> see motorware (<drive>:\ti\motorware\motorware_1_01_00_16\docs\labs\instaspin_labs.pdf)
- TMS320F28069MPZT overview and datasheet:
<http://www.ti.com/lit/ug/spruh18g/spruh18g.pdf>

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CAUTION

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- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.

- Consult the dealer or an experienced radio/TV technician for help.

3.2 Canada

3.2.1 For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247

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Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

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