SDI TAPAS - Community Inverter - Quick-Start Guide

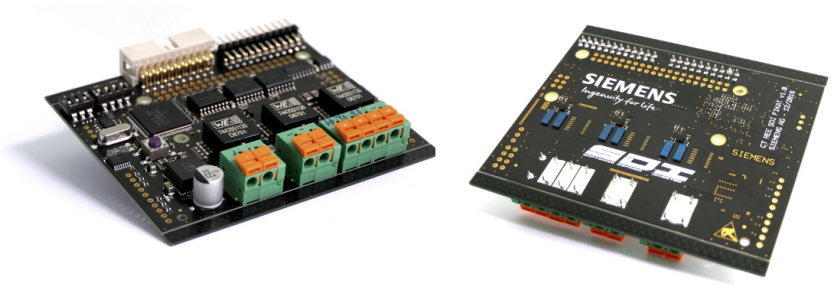

Figure 1: PCB

Use your TAPAS board with Raspberry PI or Texas Instruments InstaSPIN

!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 experts at universities and in the industry.

TAPAS features a 48V, 3-phase GaN power stage with on-board filters. This design-choice allows for a high switching frequency/bandwidth (300kHz and beyond) whilst producing a smooth output wave-form. In contrast, commonly available IGBT or MOSFET converter boards typically have a rather 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, 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 quadrocopters 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 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 & lead-design - TAPAS)

Created by :

SIEMENS

Ingenuity for life

Figure 2: SIEMENS LOGO

SIEMENS SDI (Software Defined Inverter) * in-house start-up for I/Os

Components sponsored by:

Technology by TEXAS INSTRUMENTS EPC EFFICIENT POWER CONVERSION WE WÜRTH ELEKTRONIK Allegro

Figure 3: SPONSORS LOGO

Texas Instruments http://www.ti.com

Efficient power conversion (EPC) http://epc-co.com

WÜRTH ELEKTRONIK http://www.we-online.com

Allegro Microsystems 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 smooth output voltage
- Texas Instruments C2000 Piccolo (TMS320F28069M) DSP - InstaSPIN-enabled
- CAN, GPIO, UART, SPI, 2 x QEP (encoder) interface onboard
- Raspberry-Pi compatible

TAPAS pinout

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. If you don't own a 3D printer, many local 3D printing services are available on-line. Print with temperature-stable materials like ABS (not PLA).

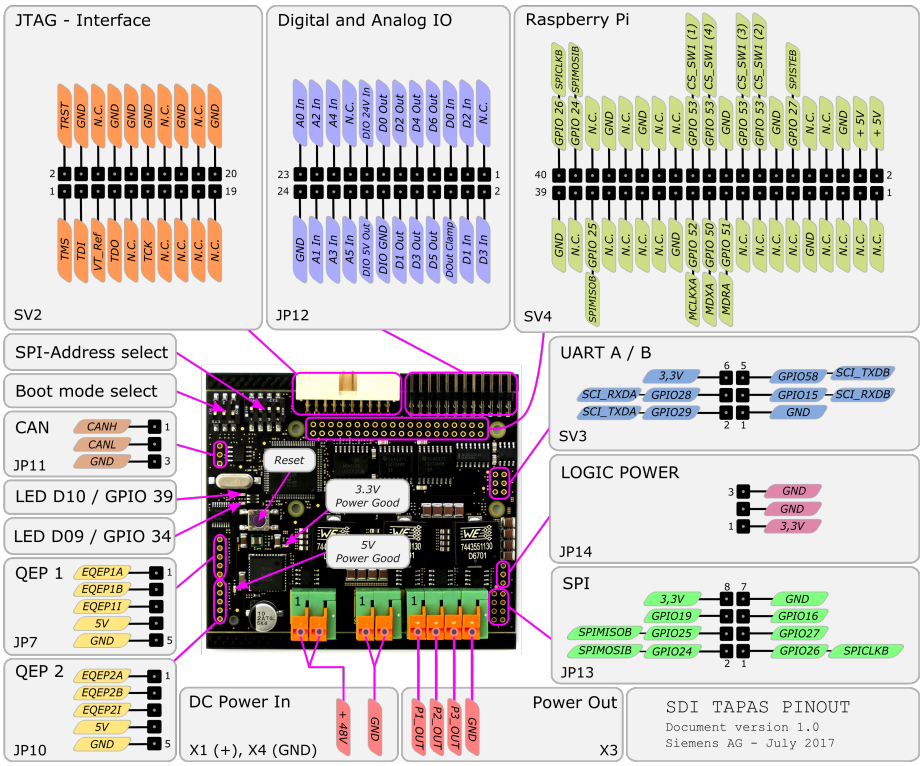

Figure 4: TAPAS PINOUT

- **DC power supply** with a minimum of 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 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 TAPAS with **Raspberry PI** we recommend a Raspberry PI Zero (W)
- If you want to use TAPAS with **Raspberry PI** we also recommend the following parts for mechanical stability:
  - 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)

Note: Difference between FIKAT (TAPAS pre-release version) and TAPAS (release version)

There are some PCB differences between the pre-release version (code-name FIKAT - PCB with Siemens & SDI logo) and release version 1.0 (code-name TAPAS - PCB with Siemens and manufacturer logos)

- The connector of the OLIMEX programmer does not fit directly to the JTAG-interface connector SV2 on the FIKAT-board, you have to solder an adapter here for being able to program the DSP on the board. The pinning of SV2 on FIKAT does match with the one of the programmers' connector. This has been fixed for TAPAS V1.0

- TAPAS has more PINs of the Raspberry-Pi socket (SV4) connected to GND. On FIKAT only pins 34 and 39 are connected to GND. Hence you cannot use a Nano Pi with FIKAT as the GND connection is missing.
- The SPI-Chip select signal (GPIO53) is connected to pin26 of SV4 via the address DIP-switch (2) on FIKAT. This has moved to pin 16 of SV4 on TAPAS.
- The resistor R_MISO_1 is populated on FIKAT but not on TAPAS.
- The resistors R_TXA1, R_RXA1, R_TXB1 and R_RXB1 are populated on FIKAT but not on TAPAS.
- The 0Ohm gate resistors R19, R23, R20, R24, R12, R14, R16, R15, R17, R18, R22, R21 on FIKAT have been changed to 2,2Ohm on TAPAS
- The DC-bus capacitor C10 for the 5V-voltage regulator U99 has been upgraded from a standard SMD-electrolytic type on FIKAT to a 39µF polymer type on TAPAS. It can now handle a higher DC ripple current on the dc-bus

- We added a TVS-clamping-diode for DC over voltage protection on TAPAS. (Not available on FIKAT). This is to absorb some of the breaking energy if the user forgot to use a breaking chopper
- The isolation ICs IC5, IC6 and IC7 on FIKAT have been swapped for a different type on TAPAS - this should have no influence on the behaviour

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:

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

We included a copy of TI motorware in the cloned repository (*motorware.zip*). Alternatively you can download motorware from Motorware or here https://github.com/SDI-SoftwareDefinedInverter/TAPAS/blob/master/motorware.zip.

As the TAPAS board definition is not part of the stock motorware package we have to make some modifications to it. All the necessary changes are contained in the patch-file *SDITAPASmotorwarePatch.patch*. Now copy *SDITAPASmotorwarePatch.patch* to the motorware installation folder (usually *C:\ti*) and start git in bash mode (also in the motorware installation folder). Then execute the following commands:

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

This completes the installation of motorware und you can start playing with the motorware-labs and the quick-start demo firmware. To add 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\instaspin_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 in the

selected directory. Here you can choose, for example, the *"TAPAS_quick_start"* project which represents the stock demo firmware to be used with the python - script for 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 consider the *"InstaSPIN Projects and Labs User's Guide"* which comes with the motorware-installation and is located in *<drive>:\ti\motorware\motorware_1_01_00_16\docs\labs\instaspin_labs.pdf* of the motorware installation.There you can find further information on 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 labs are designed to drive two motors independently - this is 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 also created a TAPAS-webapp to test all external I/O hardware. You can download it from:

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

Unzip the file place it in:

`<drive>:\ti\guicomposer\webapps\`

4. FREQUENTLY ASKED QUESTIONS / TROUBLE SHOOTING

Q: Where can I get a TAPAS board

A: For now drop a board request in the issues tracker. We will update update this section if more boards become available.

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 : http://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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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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Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

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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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8.1 General Limitations. IN NO EVENT SHALL Siemens BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS, REGARDLESS OF WHETHER Siemens HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST Siemens MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

8.2 Specific Limitations. IN NO EVENT SHALL Siemens' AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO Siemens BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9.Return Policy. Except as otherwise provided, Siemens does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact Siemens. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10.Governing Law: These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and Siemens may seek injunctive relief in any United States or foreign court.

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