This user’s guide describes the characteristics, setup and use of the TCA7408EVM/TCA5405EVM Evaluation Module (EVM). This user’s guide includes set-up instructions, a schematic diagram, a bill of materials, printed-circuit board layout drawings, software instructions, and operation instructions.

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1 Introduction

The TCA7408-5405EVM is designed to show the used of multiple TI products on a single evaluation board. It shows how the single-wire 5-bit output expander TCA5405 is used to generate LED blinking functions. The Single wire interface is implemented using a single GPIO port on the MSP430, and very simple firmware embedded in the device. The TCA7408 GPIO expander is used to an input handler, that detects Key presses and notifies the MSP430. The EVM also has the TPL0401 that is used for RGB color mixing in conjunction with the TLC59108.
1.1 **Features**

- Works with MSP430 Launchpad
- Illustrates the use of TPL0401DPOT for color mixing
- TCA7408 used for Key press detection
- Shows the use of Single wire self timed interface in TCA5405
- Color mixing and LED blinking control

1.2 **TPL0401A/B**

The TPL0401 is an I2C bus controlled, single channel, linear-taper digital potentiometer with 128 wiper positions. TPL0401A/B have an end-to-end resistance of 10k ohms and the low terminal internally connected to ground.

1.3 **TCA5405**

The TCA5405 is a 5-bit output expander controlled using a single wire input. This device is ideal for portable applications as it has a wide VCC range of 1.65V to 3.6 V. The TCA5405 uses a self-timed serial data protocol with a single data input driven by a master device synchronized to an internal clock of that device.

1.4 **TCA7408**

This 8-bit I/O expander for the two-line bidirectional bus (I2C) is designed to provide general-purpose remote I/O expansion via the I2C interface [serial clock (SCL) and serial data (SDA)]. The major benefit of this device is its wide VCC range. It can operate from 1.65-V to 3.6-V on the GPIO-port side and 1.65-V to 5.5-V on the SDA/SCL side. This allows the TCA7408 to interface with next-generation microprocessors and microcontrollers on the SDA/SCL side, where supply levels are dropping down to conserve power. The TCA7408 open-drain interrupt (INT) output is activated when any GPIO set as an input has a transition to the state opposite of that in the Input Default State register and the corresponding bit in the Interrupt Mask Register is set to 0. It is used to indicate to the system master that an input has changed to a pre-determined state.

1.5 **TLC59108**

The TLC59108 is an I2C bus controlled 8-bit LED driver that is optimized for red/green/blue/amber (RGBA) color mixing and backlight application for amusement products. Each LED output has its own 8-bit resolution (256 steps) fixed-frequency individual PWM controller that operates at 97 kHz, with a duty cycle that is adjustable from 0% to 99.6%. The individual PWM controller allows each LED to be set to a specific brightness value. An additional 8-bit resolution group PWM controller has both a fixed frequency of 190 Hz and an adjustable frequency between 24 Hz to once every 10.73 seconds, with a duty cycle that is adjustable from 0% to 99.6%. The group PWM controller dims or blinks all LEDs with the same value. TLC59108 scales up the reference current set by the external resistor (Rext) to sink the output current (Iout) at each output port.

1.6 **Requirements**

In order to operate this EVM, the following components must be connected and properly configured.

1.6.1 **LaunchPad**


**NOTE:** IMPORTANT: The code to control the TCA7408EVM/TCA5405EVM was written from an MSP430G2553 and will not work with the MSP430 chips that are included with the LaunchPad kit.
1.6.2 Power Supply (*Optional)

To ensure correct functionality of the LEDs a 5V supply at 300mA is recommended (refer to note in section 2.3.1). If not using a USB cable to power the LaunchPad a 3.3V power supply at 200mA is required.

2 Setup

This section describes the jumpers and connectors on the EVM.

2.1 Connectors and Jumpers

2.1.1 J1 & J2 – LaunchPad Headers

These connectors mate with the male headers on the LaunchPad.

2.1.2 J3 – External LED Power

This connector is where the external +5V supply is attached to power the two RGB LEDs.

2.1.3 J4 – TCA7408 GPIO

This is a pin out of the four unused GPIO pins from the TCA7408, GPIO4-GPIO7.

2.1.4 J5 – Feedback loop

For the TPL0401A to function as a voltage reference circuit the negative feedback loop must be shorted, placing a jumper across this header will short the inverting input to the output.

2.1.5 J6 – LED or Op-amp

This header controls what the TPL0401B is attached to. When shorted across position 1 and 2 the TPL0401B is connected in series with the external resistor to control the current through the LED driver. When shorted across position 2 and 3 the TPL0401B is connected to the inverting input of the op-amp to change the gain of the circuit.

2.1.6 J7 – Op-amp input

This header controls the input to the non-inverting pin of the LMV321. When shorted across position 1 and 2, the TPL0401A in a voltage divider mode is attached to the non-inverting input of the LVM321. This setup is used to test the voltage reference setup. When shorted across pins 2 and 3, the SMA connector is attached to the non-inverting input.

2.1.7 J9 – Test Points

This connector offers test points for the serial data lines, SDA, SCL and the DIN that drives the TCA5405.

<table>
<thead>
<tr>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>J1, J2</td>
<td>Connectors to interface with LaunchPad</td>
</tr>
<tr>
<td>J3</td>
<td>External 5V for LED</td>
</tr>
<tr>
<td>J4</td>
<td>GPIO4-GPIO7 from TCA7408</td>
</tr>
<tr>
<td>J5</td>
<td>Control jumper to short feedback loop</td>
</tr>
<tr>
<td>J6</td>
<td>Jumper to control LED or Op-Amp</td>
</tr>
<tr>
<td>J7</td>
<td>Jumper to control input to Op-Amp</td>
</tr>
<tr>
<td>J8</td>
<td>SMA/B Footprint for external input</td>
</tr>
<tr>
<td>J9</td>
<td>Test points for DIN, SDA and SCL</td>
</tr>
</tbody>
</table>
2.2 Hardware Setup

There are three different modes that the EVM can be used in, LED mode, Voltage reference mode, and Variable gain mode. To setup any of these three modes, begin by connecting the EVM to the LaunchPad. Note the location of the VCC and GND pins on headers J1 and J2 on both the LaunchPad and the EVM to ensure correct installation.

Install a shorting jumper across pins 1 and 2 of J6. Connect an external +5V supply to J3 and either connect the LaunchPad to a computer through USB or connect a 3.3V power supply to J6* on the LaunchPad to power it up.

NOTE: It can be possible to power up the LEDs by connecting a wire from the VCC pin of J6 on the LaunchPad to the positive pin of J3. A 5V supply might be required because the max voltage drop across the blue LED plus the drop across the TLC59108 is larger than the supply voltage of the LaunchPad.

3 Operation

The TCA5405 will control when D1-D5 light up. TPL0401B is connected in series to the REXT of the TLC59108 LED driver this setup will control D6 and D7. Each color is set to a fixed PWM to ensure baseline brightness is similar. Color mixing is then accomplished through unique methods. The desired current is set by changing the W-L resistance of the TPL0401B and the desired LED is switched on. This repeats for the other colors and then starts over. The LEDs are multiplexed at about 1000 Hz.

After setting up the EVM as described in section 2.3.1, LEDs D1-D5 should be blinking and D6 and D7 will be blue. To increase the speed at which D1-D5 blink press SW1 and to decrease the speed press SW2.

There are 25 different colors that can be created with D6-7 starting with blue and ending with green. To step through the colors from blue to green press S4. To step through the colors from green to blue press S3.

4 MSP430 Code

4.1 TCA5405

Within the source code for the MSP430 there are two different methods to handle sending data to the TCA5405. This section will explain how the TCA5405 functions and how the MSP430G2xx3 code works.
4.1.1 TC5405 Overview

As shown in Figure 1, a ten bit serial transfer is required to set the five outputs on the TCA5405. The first four bits, 0101 (S0-S3), act as a start flag for the TCA5405. S0 is a start bit and S1-S3 are the clock sense bits for the TCA5405. The next five bits (D4-D0) are the data bits associated with each of the outputs. The tenth bit returns the serial line back to high to ready the TCA5405 for the next input.

In the source code there are two methods to handle this communication. These functions are located in Single_Wire.c

1. Use a GPIO (general purpose input/output) and a clock delay to emulate S0-D0.
2. Use one of the MSP430 timers to change the output at a specified bit interval.

4.1.2 bit_bang_TCA5405_byte(unsigned char byte)

The function bi_bang_TCA5405_byte(unsigned char byte) will emulate the required ten bits for communication with the TCA5405. This function works very simply by driving a GPIO pin to high or low and utilizing the _delay_cycles() function to hold the value. After each assert on the GPIO pin a _delay_cycles(16) is called to wait roughly 2 microseconds before the next bit. The section that handles the data bits (D4-D0) only uses a _delay_cycles(10) function; this is to adjust for the time spent on if statements.

4.1.3 send_TCA5405_byte

The function send_TCA5405_byte(unsigned char byte) along with 5405_Timer_ISR() implements the required serial data by using one of the MSP430 timers. When a byte is sent to send_TCA5405_byte(), the function adds the start flag (S0-S3) to the beginning and the stop bit (1) to the end (LSB), stores the new value to a global variable, and enables the timer interrupts. After a set number of clock cycles defined by NEXT_BIT_TIME, 5405_Timer_ISR() is called and adjusts the output of the P2.0 accordingly.

NOTE: The start flag S0-S3 is hard coded into each of these methods
5 Schematics, Layout, and Bill of Materials

5.1 Schematics

Figure 2. TCA5405, TCA7408 Schematic
Figure 4. TPL0401 Schematic
5.2 Layout

Figure 5. Routing, Assembly and Silkscreen Top
Figure 6. Layer 2 Power Plane
Figure 7. Layer 3 Ground Plane
Figure 8. Routing and Assembly Bottom
### Table 2. TCA7408EVM/TCA5405EVM Bill of Material

<table>
<thead>
<tr>
<th>Qty</th>
<th>RefDes</th>
<th>Value</th>
<th>Description</th>
<th>Part Number</th>
<th>MFG</th>
<th>Notes</th>
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<tbody>
<tr>
<td>4</td>
<td>C1-4</td>
<td>0.1µ</td>
<td>Capacitor, Ceramic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>C5</td>
<td>10µ</td>
<td>Capacitor, Ceramic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>C6</td>
<td></td>
<td>Capacitor, Ceramic</td>
<td></td>
<td></td>
<td>DNI</td>
</tr>
<tr>
<td>1</td>
<td>J8</td>
<td></td>
<td>Connector, SMA , Straight, PC mount</td>
<td>901-144-BFX</td>
<td>AMP</td>
<td>DNI</td>
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<tr>
<td>5</td>
<td>D1-5</td>
<td>SML-P12PTT86</td>
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<td>SML-P12PTT86</td>
<td>ROHM</td>
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<tr>
<td>2</td>
<td>D6-7</td>
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<td>Kingbright</td>
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<td>Sullins</td>
<td>spacing</td>
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<td>spacing</td>
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<td>PPTC101LFBN-RC</td>
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<td>J9</td>
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<td>DNI</td>
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<td></td>
</tr>
<tr>
<td>10</td>
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<td>10k</td>
<td>Resistor, Chip, 1/16W 5%</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>R5-9</td>
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<td>R10</td>
<td>250</td>
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<td></td>
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<tr>
<td>1</td>
<td>R12</td>
<td>[value]</td>
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<td>5001</td>
<td>Keystone</td>
<td></td>
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<tr>
<td>1</td>
<td>TP1</td>
<td>5013</td>
<td>Test Point, Orange, Thru Hole</td>
<td>5013</td>
<td>Keystone</td>
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<tr>
<td>4</td>
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<td>EVQ221304M</td>
<td>Switch, SPST, 20-ma, 15-V</td>
<td>EVQ221304M; EVQ21305R; EVQ21307K</td>
<td>Panasonic</td>
<td>Prefer EVQ21304M if unavailable use 305R or 307K</td>
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<tr>
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<td>U3</td>
<td>LMV321IDBVR</td>
<td>IC Low Power Single Op-amp</td>
<td>LMV321IDBVR</td>
<td>TI</td>
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<td>TCA5405RUG</td>
<td>IC, Low Voltage 5-Bit Self-Timed, Single-Wire Output Expander</td>
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<td>IC, Low-Voltage 8-Bit I2C and SMBus I/O Expander</td>
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<td>TI</td>
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For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant

Caution

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.
FCC Interference Statement for Class B EVM devices

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- 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.

For EVMs annotated as IC – INDUSTRY CANADA Compliant

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Changes or modifications not expressly approved by the party responsible for compliance could void the user’s authority to operate the equipment.

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This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concerning EVMs including detachable antennas

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.

Concernant les EVMs avec appareils radio

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

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 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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1. Use this product in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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[URL: http://www.tij.co.jp]

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EVALUATION BOARD/KIT/MODULE (EVM)
WARNINGS, RESTRICTIONS AND DISCLAIMERS

For Feasibility Evaluation Only, in Laboratory/Development Environments. Unless otherwise indicated, this EVM is not a finished electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.

2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard.

3. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.

4. You will take care of proper disposal and recycling of the EVM’s electronic components and packing materials.

Certain Instructions. It is important to operate this EVM within TI’s recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM User’s Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, some circuit components may have case temperatures greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User’s Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

Agreement to Defend, Indemnify and Hold Harmless. You agree to defend, indemnify and hold TI, its licensors and their representatives harmless from and against any and all claims, damages, losses, expenses, costs and liabilities (collectively, “Claims”) arising out of or in connection with any use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate the components for possible use in safety critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

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