LP5521TM Evaluation Kit

National Semiconductor
AN-1632
Tomi Koskela
January 16, 2009

General Description

The LP5521 is a three channel LED driver designed to produce variety of lighting effects for mobile devices. High efficiency charge pump enables LED driving over full Li-Ion battery voltage range. The device has a program memory for creating variety of lighting sequences. When program memory has been loaded, LP5521 can operate independently without processor control.

LP5521 maintains excellent efficiency over a wide operating range by automatically selecting proper charge pump gain based on LED forward voltage requirements. LP5521 is able to automatically enter power-save mode, when LED outputs are not active and thus lowering current consumption.

Three independent LED channels have accurate programmable current sources and PWM control. Each channel has program memory for creating desired lighting sequences with PWM control.

LP5521 has a flexible digital interface. Trigger I/O and 32 kHz clock input allow synchronization between multiple devices. Interrupt output can be used to notify processor, when LED sequence has ended. LP5521 has four pin selectable I2C addresses. This allows connecting up to four parallel devices in one I2C bus. GPO and INT pins can be used as a digital control pin for other devices.

LP5521 requires only four small ceramic capacitors.

LP5521 is available in tiny 2.1x1.7x0.6 mm microSMD-20 package and in 4.0x5.0x0.8 mm bumped LLP-24 package.

Evaluation Kit Overview

LP5521 Evaluation Kit is based on computer controlled system, where the actual LP5521 devices are controlled and powered through USB interface. Also external power can be used if wanted. Two different sets of LEDs can be selected, either white LEDs or RGB LEDs. Four LP5521TM devices are assembled on one board to be able to evaluate the triggering/sequencing of multiple devices in one application.

The kit supports complete functional evaluation of the circuit. The evaluation kit consists of:

* LP5521 evaluation board
* USB interface cable
* CD—ROM including:
    — Evaluation software
    — Command compiler software
    — Demo sequences
    — LP5521 datasheet
    — LP5521 power saving application note
    — LP5521 programming application note
    — Evaluation kit document (this doc.)
   — MicroSMD-20 PCB layout guidelines
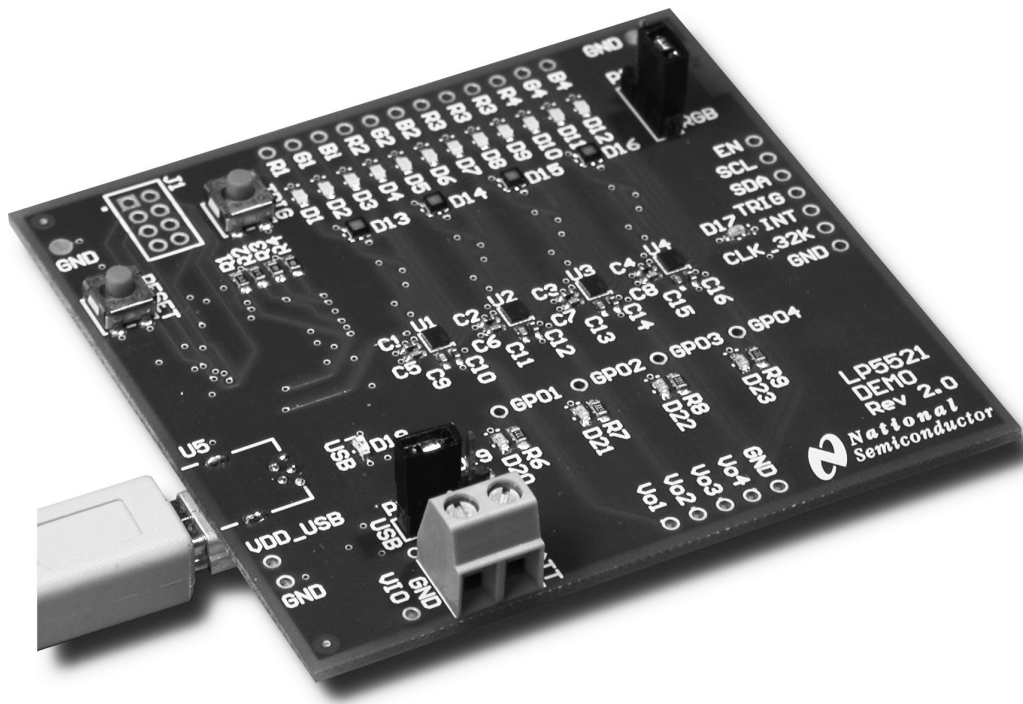
30019715

FIGURE 1. LP5521 Evaluation Board

www.national.com

Evaluation Software, Full Access

Two versions of the LP5521 evaluation software and some support files are supplied on the delivery CD together with all available documentation regarding the circuit. Full access software allows control of all of the LP5521 features, and easy software is intended for users needing control only for the basic features. The program and the support files must be in the same folder. The software can be run by double clicking its icon. The software does not require any installation.

In the middle of the control panel is shown the register map of LP5521. There are separate tabs for all four LP5521. By default registers reflect immediately the changes you make by clicking the buttons or sliders. When Auto Write is disabled Enable and Op Mode registers can be written by clicking Write button. In the upper part of the control panel there is Direct Access and SRAM Memory Data controls.
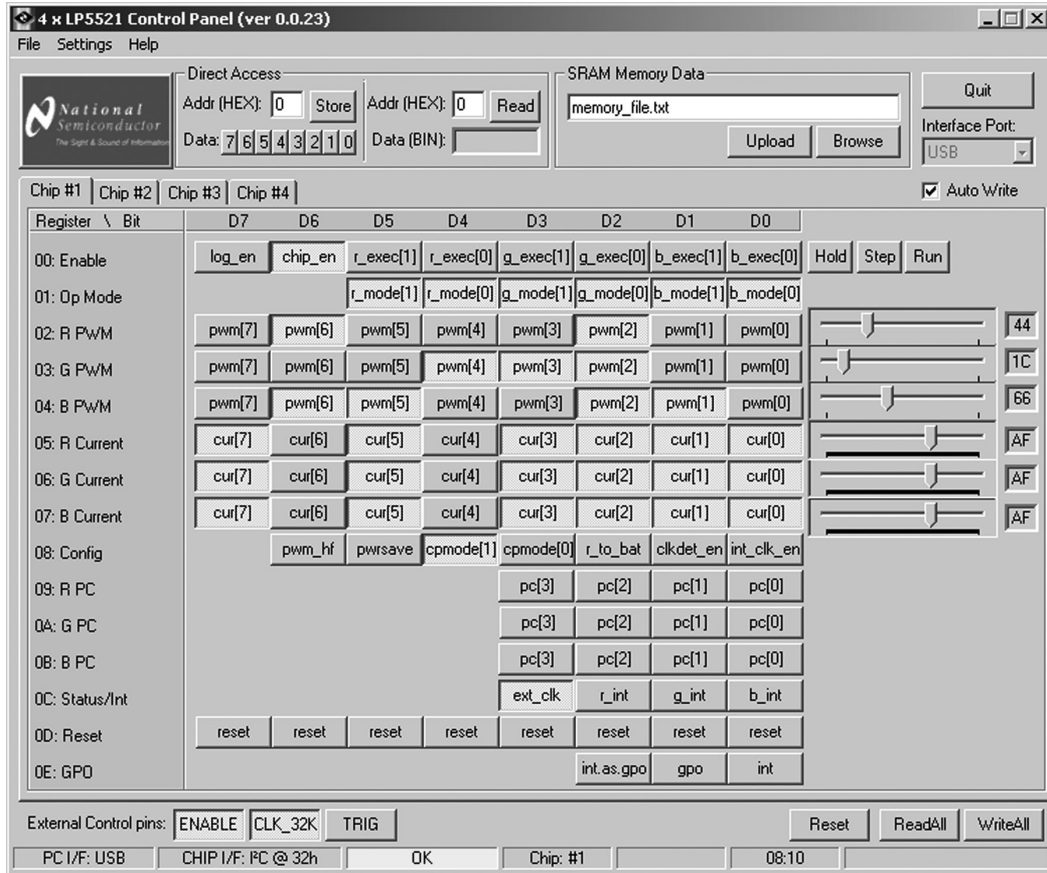
30019702

FIGURE 2. LP5521 Evaluation Software User Interface

DIRECT ACCESS

In the upper left side there is register data store control and in the right side register read control. User can store data to LP5521 registers by clicking Data selection buttons, typing address in hexadecimal to Addr (HEX) column. Data will be stored to register when Store button is clicked. User can read data by typing address to Addr (HEX) column. Register data will be read when Read button is pressed. Register addresses can be seen on the left side of the Control Panel. E.g. 00: Enable is enable register and the hexadecimal address is 00.

SRAM MEMORY DATA

LP5521 has program memory for storing LED commands. LP5521 can store 16 commands for each channel (R, G, B). LED patterns can be written to memory by browsing memory file (*.bin) and clicking then Upload button. Pressing the Upload button sets the chip automatically to Load SRAM mode, and back to it's previous state. The evaluation kit CD includes

example memory files. User can write own memory files by using Command compiler, which translates ASCII commands in to memory file. After file is selected, it must me send to LP5521 SRAM memory by pressing the Upload button.

EXTERNAL CONTROL PINS

On bottom left corner there are external pin controls.

-ENABLE button sets the EN pin high/low

-CLK_32K button enables external clock generation from USB

-TRIG button sends external trigger signal to TRIG pin. Same effect can be achieved with the TRIG button on the evaluation board

EXECUTION CONTROL BUTTONS

Hold, Step and Run buttons can be used for controlling the execution of the program. By default the state is Hold, and to be able to start the program Run button must be pressed. With

Step button program can be executed one command at a time.

Evaluation Software, Easy

Easy software (LP5521x4easy.exe) is intended for users needing control only for the basic features. With the General Control all LP5521 chips can be enabled at the same time and charge pump set to for example 1.5x mode. There are separate tabs for each chip. Program file can be selected for each chip, and after file is selected the Upload button send the program to LP5521 SRAM memory. With Run button the LP5521 is set to run mode, and it starts executing the program. It is good practice to use "wait for external trigger" as the first

command on each chips' program, then it is possible to start all sequences at the same time with external trigger signal.

With Current and PWM control sliders it is possible to control RGB LEDs brightness manually, without programming sequences.

Logarithmic brightness enables logarithmic PWM brightness control to make visual effect of some ramps more pleasing to the eye.
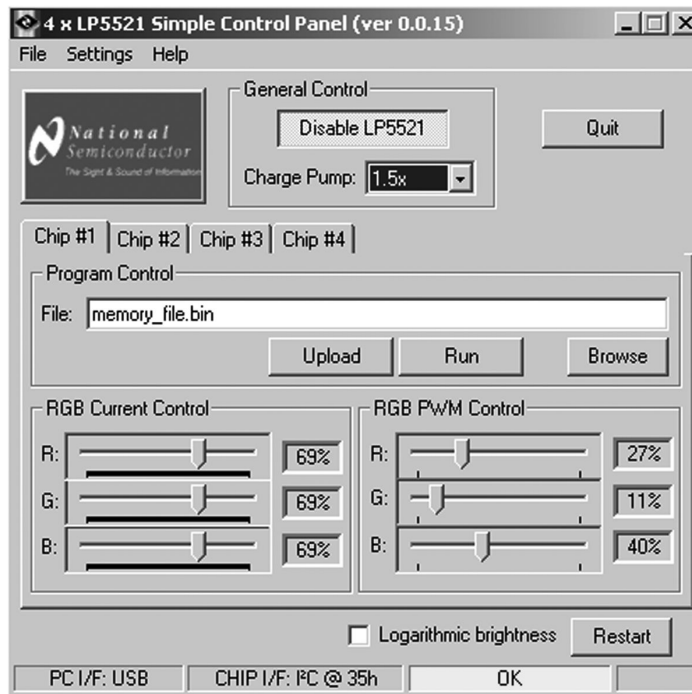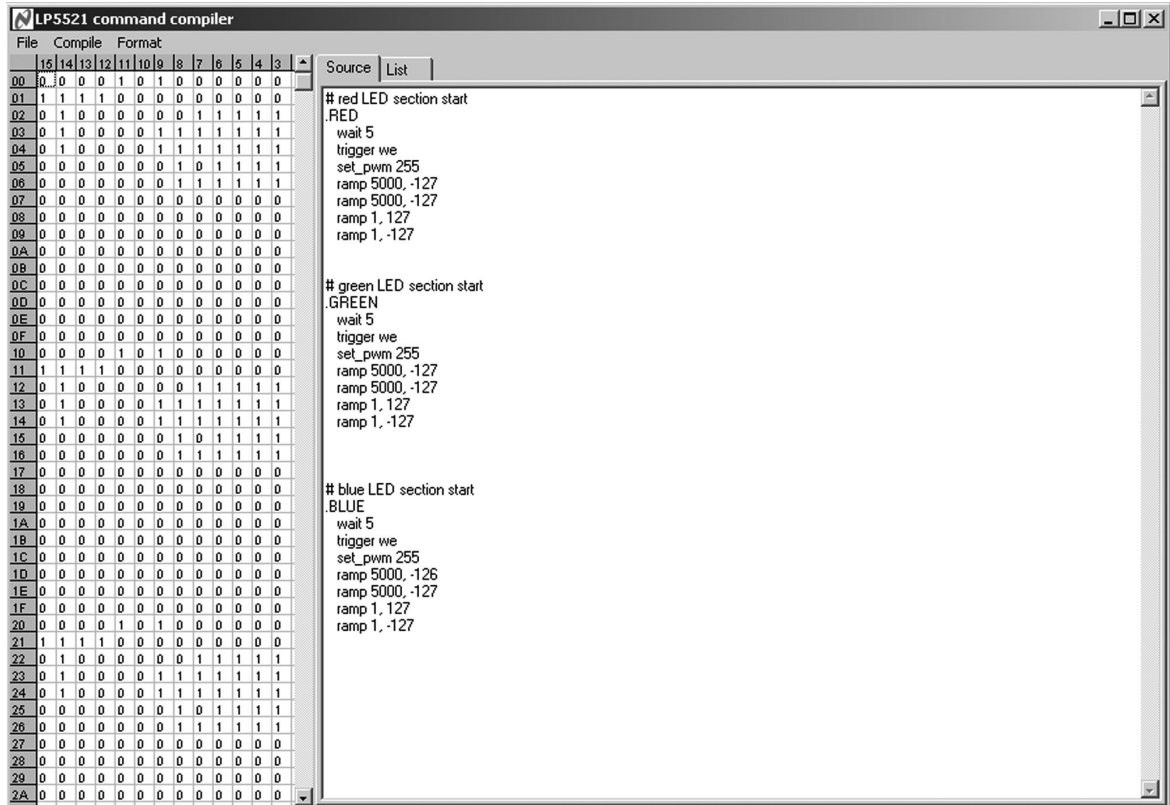

30019714

FIGURE 3. LP5521 Easy Evaluation Software User Interface

www.national.com

Command Compiler

Command compiler is used to write LED sequences for the LP5521. Command compiler is a simple to use Windows program with graphic user interface.

User can write own memory files by using command compiler's editor or any text editor (file must have .src extension). Command compiler translates ASCII memory files in to binary file (.bin), or hex file (.hex). In the Format menu user can select between .bin and .hex formats. Evaluation software uses .bin format, but .hex format can be used for user own applications. To start command compiler, double click the compiler icon (**compiler.exe**). Source file can be opened from File/Open menu. Source files have .src extension. When source tab has been selected source code is visible and it can be modified, compiled and saved. File must be created first to be able to edit it, for example open some demo sequence, and save it with another name. Command compiler does not have "New" option on File menu. Below is syntax and explanation for Command compiler commands. Program can be compiled to binary or hex formats with compile menu. After compilation, command list can be seen by clicking List tab. Compilation generates binary/hex file and list file. Compiled file has 16 commands for each channel which is total of 48 commands. File represents the whole SRAM program memory content.

```
LP5521 command compiler

File   Compile   Format

[ Source | List ]

# red LED section start
.RED
    wait 5
    trigger we
    set_pwm 255
    ramp 5000, -127
    ramp 5000, -127
    ramp 1, 127
    ramp 1, -127

# green LED section start
.GREEN
    wait 5
    trigger we
    set_pwm 255
    ramp 5000, -127
    ramp 5000, -127
    ramp 1, 127
    ramp 1, -127

# blue LED section start
.BLUE
    wait 5
    trigger we
    set_pwm 255
    ramp 5000, -126
    ramp 5000, -127
    ramp 1, 127
    ramp 1, -127
```

Addr	15	14	13	12	11	10	9	8	7	6	5	4	3
00	0	0	0	0	1	0	1	0	0	0	0	0	0
01	1	1	1	0	0	0	0	0	0	0	0	0	0
02	0	1	0	0	0	0	0	1	1	1	1	1	1
03	0	1	0	0	0	0	1	1	1	1	1	1	1
04	0	1	0	0	0	0	1	1	1	1	0	1	1
05	0	0	0	0	0	0	0	1	0	1	1	1	1
06	0	0	0	0	0	0	0	1	1	1	1	1	1
07	0	0	0	0	0	0	0	0	0	0	0	0	0
08	0	0	0	0	0	0	0	0	0	0	0	0	0
09	0	0	0	0	0	0	0	0	0	0	0	0	0
0A	0	0	0	0	0	0	0	0	0	0	0	0	0
0B	0	0	0	0	0	0	0	0	0	0	0	0	0
0C	0	0	0	0	0	0	0	0	0	0	0	0	0
0D	0	0	0	0	0	0	0	0	0	0	0	0	0
0E	0	0	0	0	0	0	0	0	0	0	0	0	0
0F	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	1	0	1	0	0	0	0	0	0
11	1	1	1	0	0	0	0	0	0	0	0	0	0
12	0	1	0	0	0	0	0	1	1	1	1	1	1
13	0	1	0	0	0	0	1	1	1	1	1	1	1
14	0	1	0	0	0	0	1	1	1	1	1	1	1
15	0	0	0	0	0	0	0	1	0	1	1	1	1
16	0	0	0	0	0	0	0	1	1	1	1	1	1
17	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0
1A	0	0	0	0	0	0	0	0	0	0	0	0	0
1B	0	0	0	0	0	0	0	0	0	0	0	0	0
1C	0	0	0	0	0	0	0	0	0	0	0	0	0
1D	0	0	0	0	0	0	0	0	0	0	0	0	0
1E	0	0	0	0	0	0	0	0	0	0	0	0	0
1F	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	1	0	1	0	0	0	0	0	0
21	1	1	1	0	0	0	0	0	0	0	0	0	0
22	0	1	0	0	0	0	0	1	1	1	1	1	1
23	0	1	0	0	0	0	1	1	1	1	1	1	1
24	0	1	0	0	0	0	1	1	1	1	1	1	1
25	0	0	0	0	0	0	0	1	0	1	1	1	1
26	0	0	0	0	0	0	0	1	1	1	1	1	1
27	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0
2A	0	0	0	0	0	0	0	0	0	0	0	0	0

30019706

FIGURE 4. LP5521 Command Compiler User Interface

Syntax

Comment – Line starting with "#" symbol.

Example: # red LED section start

Sections – Red, green or blue LED section starts with: .RED, .GREEN or .BLUE.

Example: .RED

Labels – Any words with colon (:) as ending symbol.

Example: label1:

Commands

Ramp

Ramp command generates a PWM ramp from current value. Ramp command has two parameters – first is time in milliseconds (floating point format, maximum execution time $t_{MAX} = (1000 \text{ ms} \times \text{number of steps}) - 1 \text{ ms})$ and second is number of steps (positive or negative, integer 2-128) separated with comma.

Example: ramp 20.5,6

Wait

With wait command program execution stops for time defined. Command has one parameter, time in milliseconds (floating point format, maximum 999).

Example: wait 50.5

Branch

Branch command loads step number to program counter. Branch command has two parameters, loop counter (integer 0-63, 0 means infinite loop) and label separated with comma. Label must be predefined before using in a branch command. The following example loops 5 times commands between label1 and branch command:

Example: label1: … branch 5,label1

Set_PWM

Set_pwm command sets PWM output value. Command has one parameter, PWM value (integer 0-255).

Example: set_pwm 23

Start

(Go to) Start command resets program counter and continues executing from the beginning of section. No parameters used.

Example: start

Errors

If there is an error during compilation error message is generated. Error messages are as follows:

1 = color section error

2 = syntax error

3 = ramp parameter error

4 = SRAM memory overflow

6 = ramp step error

7 = branch error

9 = set_pwm parameter error

11 = wait parameter error

Example command file

red LED section start
.RED
ramp 20.5,6
ramp 10,-15
wait 10
green LED section start
.GREEN
ramp 10,-15
start
blue LED section start
.BLUE
ramp 10,15
end R

Trigger

Trigger command sets wait or send trigger. Command has two parameters, wait trigger channel and send trigger channel. Channels are defined as: r = red, g = green, b = blue, e = external.

Examples:

trigger sr => (Send trigger to red channel)

trigger sg => (Send trigger to green channel)

trigger sb => (Send trigger to blue channel)

trigger se => (Send trigger to external channel)

trigger sgb => (Send trigger to green and blue channel)

trigger wr => (Wait trigger from red channel)

trigger sr,wb => (Send trigger to red channel and wait trigger from blue channel)

End

End command ends program execution. Also interrupt signal can be send or program counter can be reset. Command can have up to two parameters. I = interrupt send, R = reset program counter.

Examples:

end I

end R

end R,I

end I,R (same as earlier)

end

Files

Source file has .src extension. During compilation listing file with .lst extension and binary with .bin or hex file with .hex extension will be generated. File name is the same as for source file name.

Evaluation Hardware

The evaluation board has four LP5521 circuits with the necessary external components placed around them. Test points for the signals are on the board edges. INT and TRIG lines for the four chips are tied together to make it possible to syn-

chronize four LP5521 and make interesting lighting effects. GPO and INT pins has indicator LEDs. Each chip has own I²C address.
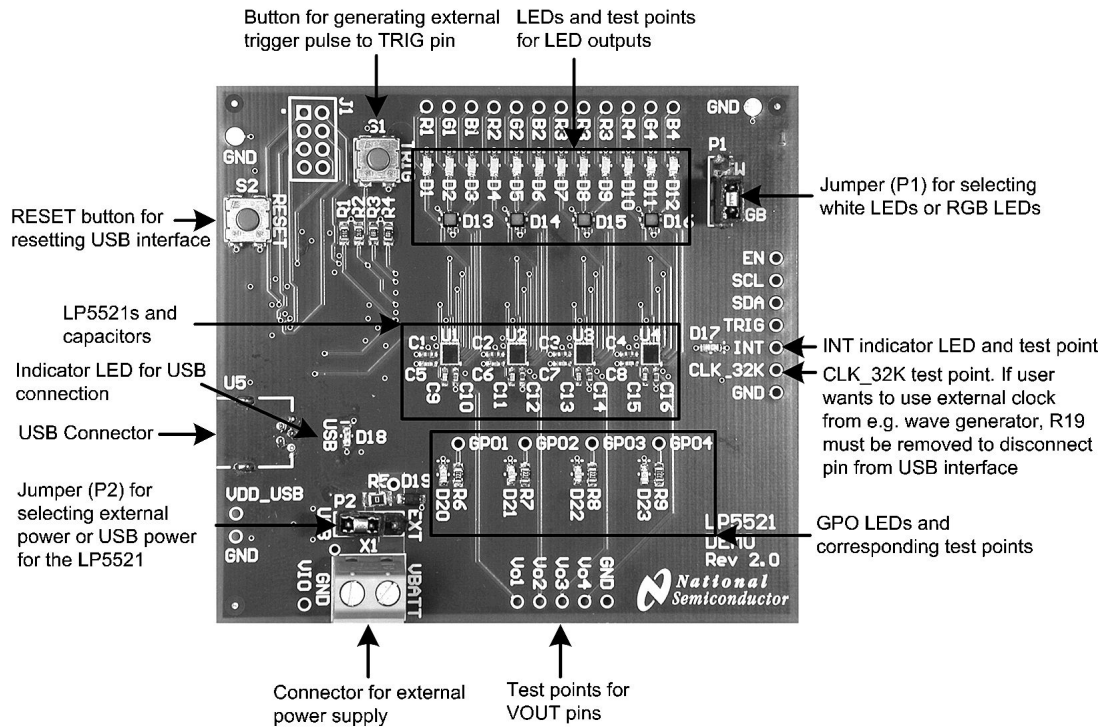

30019717

FIGURE 5. LP5521 Evaluation Board Jumper Settings

Jumper P2 on the evaluation board selects supply voltage VBATT between external power or USB power. If external power supply is used, the VBATT and ground GND can be connected in the green power connector X1. Possible supply voltage range is from 2.8V to 5.5V. When the USB powering is used, the supply voltage is 3.3V.

There are red indicator LEDs connected to the INT and GPO pins to visualize the functionality of the pins. With INT LED it is possible to see when external interrupt is sent. You can

clear the interrupt by reading the Status/INT register, or by simply pressing the Read All button on the evaluation software when the chip which has sent the interrupt is selected. Note that if INT pin is set to work as a CMOS output (EN_GPO_INT bit high) then the functionality of the LED is reverse i.e. when GPO_INT is high then the LED is off and when GPO_INT is low, then the LED is on. See evaluation board schematic for reference.

Getting Started

1. Connect the USB cable from the evaluation Kit to the USB port of your PC. When you plug in the USB cable for the first time, your operating system prompts you about "New hardware found" and installs the USB driver automatically.
2. Make sure that the jumpers on evaluation boards are set as wanted.
3. Start the software **lp5521x4.exe** by double-clicking its icon.
4. Press **ENABLE** button on the lower left corner.
5. Press **CLK_32K** button on the lower left corner. **ENABLE** and **CLK_32K** should now be pressed down.
6. Press **Read All** button, to read the current state of the control bits.
7. Enable chip and charge pump 1.5x mode by enabling the **chip_en** and **cpmode[1]** register bits.
8. Browse for **bouncing_light_4xnjoy_chip1.bin** file on SRAM memory data and press Upload button.
9. Then press **Run** button to start the sequence. First command on is "wait for external" trigger, so LEDs do not light yet.
10. Change to **Chip #X**, repeat steps 6 - 9 for all chips, but select **bouncing_light_4xnjoy_chipX.bin**
11. Press **TRIG** button on evaluation software or evaluation board to start the sequence.

12. If you want to change sequence, press browse button and select different demo program and press Upload button to write the program to chip SRAM.
13. To change the device under control press one of the Chip # tabs. Software is uploaded to each device individually.

EASY START WITH DIRECT PWM CONTROL

1. Start the Evaluation Software.
2. Press **ENABLE** button on the lower left corner.
3. Press **CLK_32K** button on the lower left corner. **ENABLE** and **CLK_32K** should now be pressed down.
4. Press **Read All** button, to read the current state of the control bits.
5. Enable chip and charge pump 1.5x mode by enabling the **chip_en** and **cpmode[1]** register bits.
6. Set to register map: **R_MODE[1:0] = 11, G_MODE[1:0] = 11, B_MODE[1:0] = 11.**
7. Adjust RED, GREEN and BLUE PWM values/sliders for LED brightness control. Cur[7:0] control bits can be used to adjust the maximum current. See *Figure 2* for correct software settings.
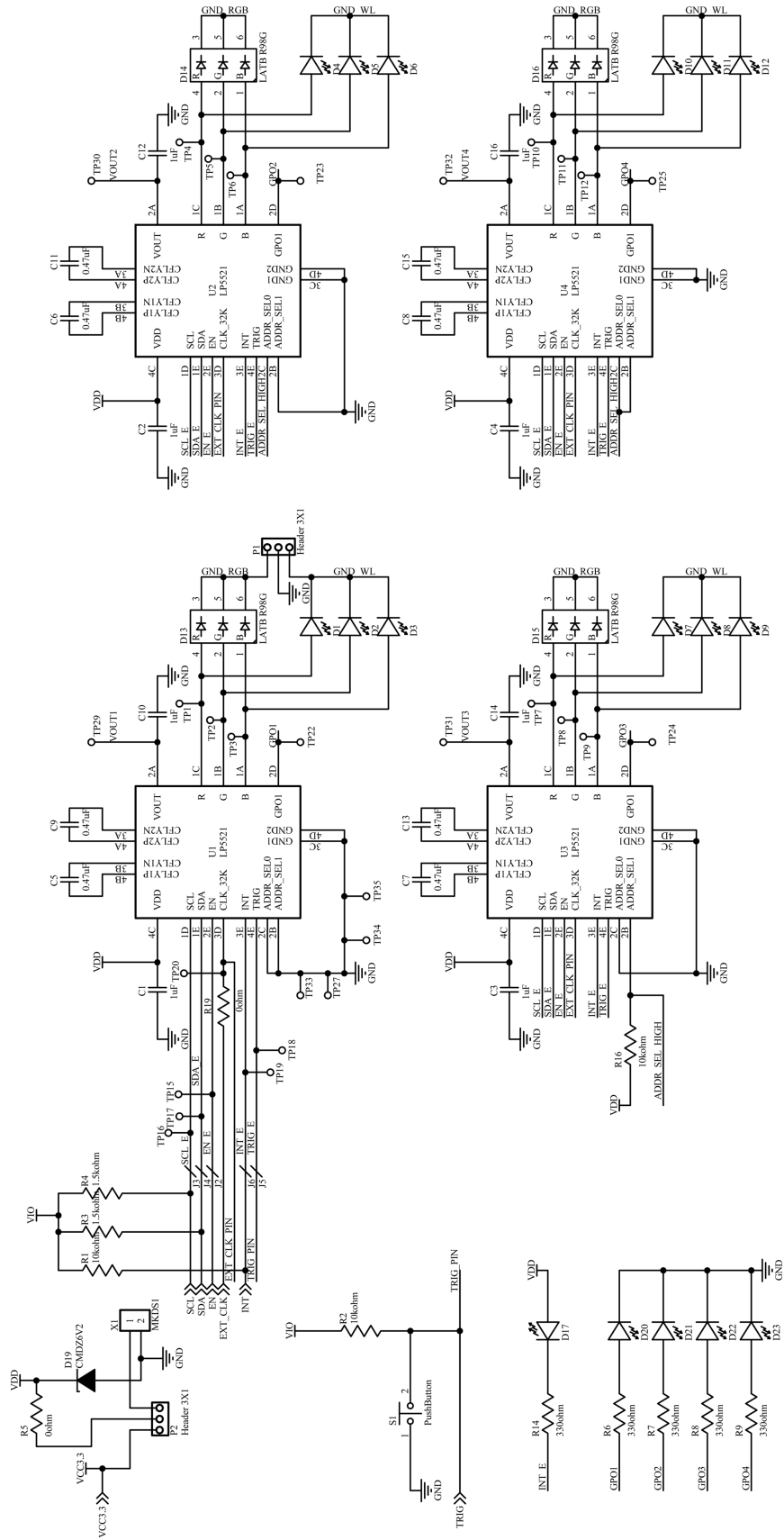8. To change the device under control press one of the Chip # tabs.

www.national.com

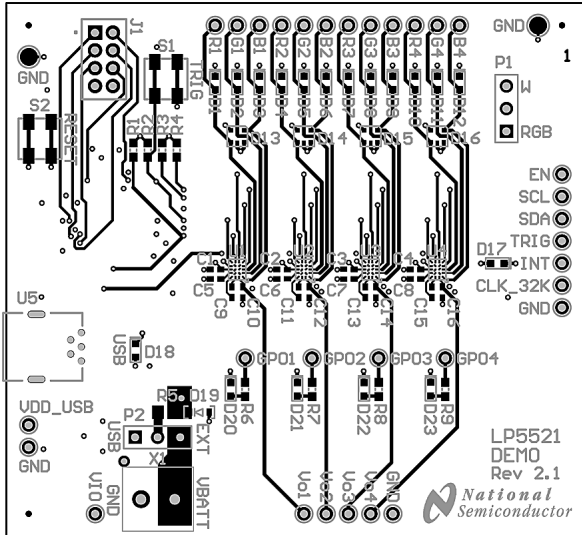**FIGURE 6. LP5521 Evaluation Board Schematic**
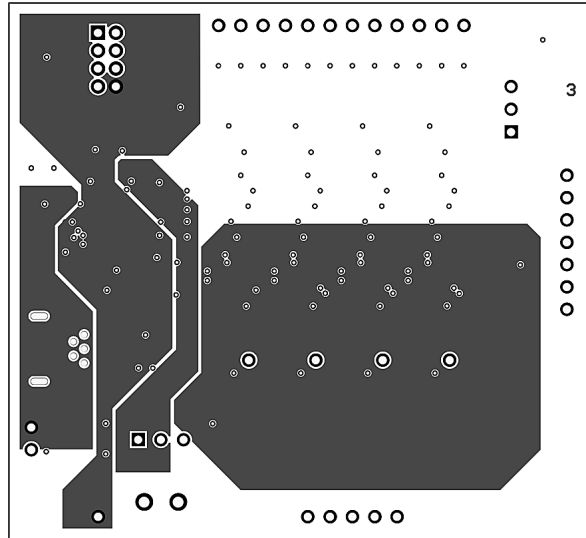
30019709

Evaluation Board Layout

The evaluation board layers are:

1. Top, component side, signal
2. GND plane
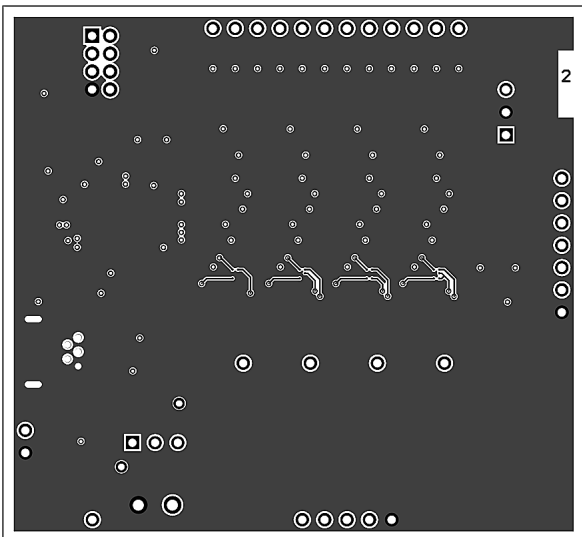3. Power plane
4. Bottom, solder side, signal

30019710
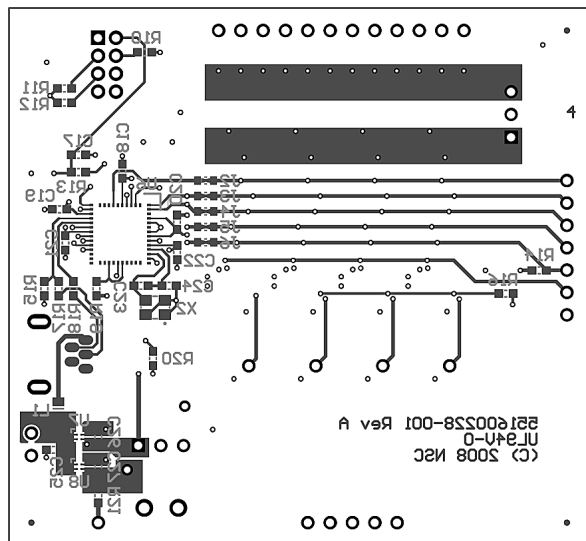
FIGURE 7. LP5521 Evaluation Board Layer 1 (Top, Signal).

30019712

FIGURE 9. LP5521 Evaluation Board Layer 3 (Power).

30019711

FIGURE 8. LP5521 Evaluation Board Layer 2 (GND).

30019713

FIGURE 10. LP5521 Evaluation Board Layer 4 (Bottom, Signal).

List of Main Components

Model	Type	Vendor	Voltage Rating	Size
Capacitor 1μF for C_{OUT} and C_{IN} (two alternatives)				
C1005X5R1A105K	Ceramic X5R	TDK	10V	0402 (1005)
ECJ0EB1A105M	Ceramic X5R	Panasonic	10V	0402 (1005)
Capacitor for 470nF for C_{FLY1-2} (two alternatives)				
C1005X5R1A474K	Ceramic X5R	TDK	10V	0402 (1005)
ECJ0EB0J474K	Ceramic X5R	Panasonic	10V	0402(1005)
LEDs				
LATB R98G	RGB chip LED	Osram	–	1.6 x 1.6mm
LW Q38G	White LED	Osram	-	0603 (1608)

Notes

For more National Semiconductor product information and proven design tools, visit the following Web sites at:

Products		Design Support	
Amplifiers	www.national.com/amplifiers	WEBENCH® Tools	www.national.com/webench
Audio	www.national.com/audio	App Notes	www.national.com/appnotes
Clock and Timing	www.national.com/timing	Reference Designs	www.national.com/refdesigns
Data Converters	www.national.com/adc	Samples	www.national.com/samples
Interface	www.national.com/interface	Eval Boards	www.national.com/evalboards
LVDS	www.national.com/lvds	Packaging	www.national.com/packaging
Power Management	www.national.com/power	Green Compliance	www.national.com/quality/green
Switching Regulators	www.national.com/switchers	Distributors	www.national.com/contacts
LDOs	www.national.com/ldo	Quality and Reliability	www.national.com/quality
LED Lighting	www.national.com/led	Feedback/Support	www.national.com/feedback
Voltage Reference	www.national.com/vref	Design Made Easy	www.national.com/easy
PowerWise® Solutions	www.national.com/powerwise	Solutions	www.national.com/solutions
Serial Digital Interface (SDI)	www.national.com/sdi	Mil/Aero	www.national.com/milaero
Temperature Sensors	www.national.com/tempsensors	Solar Magic®	www.national.com/solarmagic
Wireless (PLL/VCO)	www.national.com/wireless	Analog University®	www.national.com/AU

THE CONTENTS OF THIS DOCUMENT ARE PROVIDED IN CONNECTION WITH NATIONAL SEMICONDUCTOR CORPORATION ("NATIONAL") PRODUCTS. NATIONAL MAKES NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE ACCURACY OR COMPLETENESS OF THE CONTENTS OF THIS PUBLICATION AND RESERVES THE RIGHT TO MAKE CHANGES TO SPECIFICATIONS AND PRODUCT DESCRIPTIONS AT ANY TIME WITHOUT NOTICE. NO LICENSE, WHETHER EXPRESS, IMPLIED, ARISING BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS IS GRANTED BY THIS DOCUMENT.

TESTING AND OTHER QUALITY CONTROLS ARE USED TO THE EXTENT NATIONAL DEEMS NECESSARY TO SUPPORT NATIONAL'S PRODUCT WARRANTY. EXCEPT WHERE MANDATED BY GOVERNMENT REQUIREMENTS, TESTING OF ALL PARAMETERS OF EACH PRODUCT IS NOT NECESSARILY PERFORMED. NATIONAL ASSUMES NO LIABILITY FOR APPLICATIONS ASSISTANCE OR BUYER PRODUCT DESIGN. BUYERS ARE RESPONSIBLE FOR THEIR PRODUCTS AND APPLICATIONS USING NATIONAL COMPONENTS. PRIOR TO USING OR DISTRIBUTING ANY PRODUCTS THAT INCLUDE NATIONAL COMPONENTS, BUYERS SHOULD PROVIDE ADEQUATE DESIGN, TESTING AND OPERATING SAFEGUARDS.

EXCEPT AS PROVIDED IN NATIONAL'S TERMS AND CONDITIONS OF SALE FOR SUCH PRODUCTS, NATIONAL ASSUMES NO LIABILITY WHATSOEVER, AND NATIONAL DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY RELATING TO THE SALE AND/OR USE OF NATIONAL PRODUCTS INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS PRIOR WRITTEN APPROVAL OF THE CHIEF EXECUTIVE OFFICER AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

Life support devices or systems are devices which (a) are intended for surgical implant into the body, or (b) support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in a significant injury to the user. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system or to affect its safety or effectiveness.

National Semiconductor and the National Semiconductor logo are registered trademarks of National Semiconductor Corporation. All other brand or product names may be trademarks or registered trademarks of their respective holders.

Copyright© 2009 National Semiconductor Corporation

For the most current product information visit us at www.national.com

National Semiconductor Americas Technical Support Center Email: support@nsc.com Tel: 1-800-272-9959	**National Semiconductor Europe Technical Support Center** Email: europe.support@nsc.com German Tel: +49 (0) 180 5010 771 English Tel: +44 (0) 870 850 4288	**National Semiconductor Asia Pacific Technical Support Center** Email: ap.support@nsc.com	**National Semiconductor Japan Technical Support Center** Email: jpn.feedback@nsc.com

www.national.com