Freescale Semiconductor
Application Note

Document Number: AN4842
Rev. 1.0, 03/2014

S12ZVL LIN Enabled RGB LED Lighting Application

Based on the MC9S12ZVL32 MagniV Device

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Contents

1 Introduction

This application note introduces the MC9S12ZVL32 device in an RGB LED lighting application, capable of RGB LED control and diagnostics.

The MC9S12ZVL32 integrates a 16-bit microcontroller built on proven S12 technology, an automotive voltage regulator, a LIN interface, a VSUP module to sense automotive battery voltage and an HVI pin [1].

The RGB LED lighting application is controlled using the FreeMASTER tool [2].

Part of this document is the AN4842SW.zip file containing X-S12ZVL32-USLED hardware and software files.

2 RGB LED lighting application

Figure 1 shows the RGB LED lighting application block diagram. The blue boxes represent MC9S12ZVL32 modules and the light brown boxes represent the software modules.

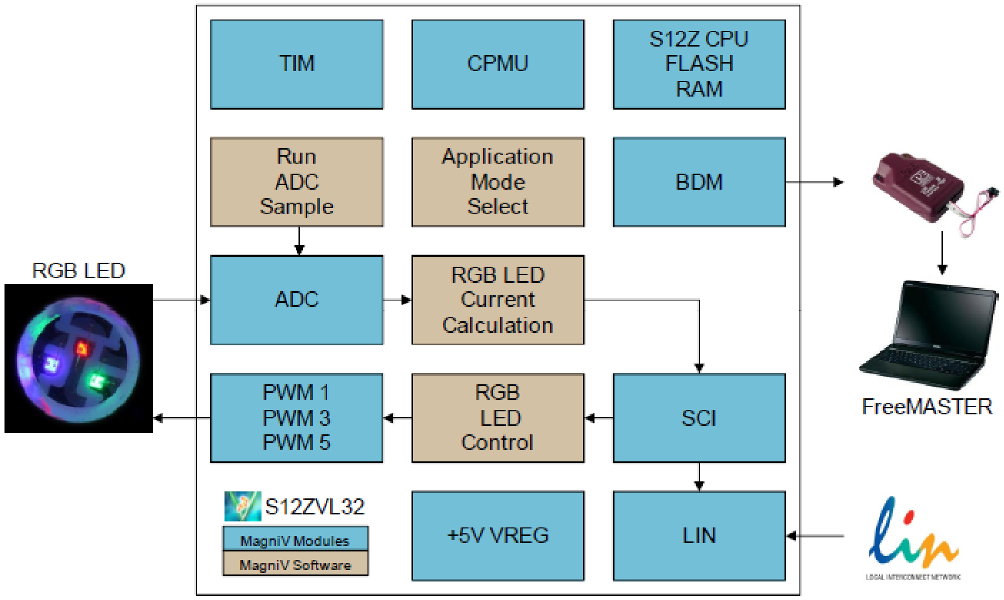

Figure 1. Application block diagram

The RGB LED is controlled using the FreeMASTER tool control page [2]. The RGB LED voltage is sensed using the ADC and recalculated to the LED average current using the AMMCLIB modules [3] to enable LED diagnostics.

The RGB LED control and diagnostics can be monitored by the LIN.

For a detailed description, see the following sections.

2.1 RGB LED application circuitry

The RGB LED is controlled by the MCU PWM1, PWM3 and PWM5 outputs, see Figure 2. The RGB LED voltage is sensed using resistors R6, R7, R8 by the MCU AN3, AN4 and AN5 inputs, see Table 1.

The MCU +5 V regulator is using the external ballast transistor Q3. The Q3 helps to reduce MCU power dissipation and extends the regulator current capability as well. The module reverse battery protection is guaranteed by diode D5.

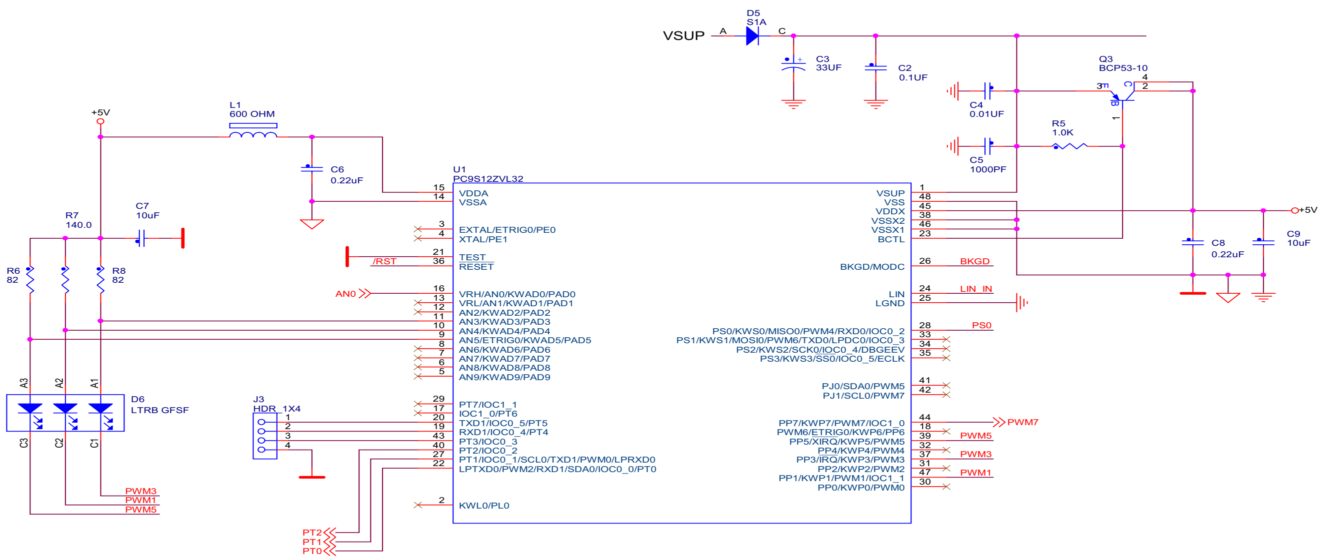

Figure 2. RGB LED application circuitry

Table 1. RGB LED D6 pin assignment

RGB LED pins	RGB LED color	RGB LED control	RGD LED diagnostic
A1, C1	Blue	PWM3	AN3
A2, C2	Red	PWM1	AN4
A3, C3	Green	PWM5	AN5

2.2 RGB LED control

The PWM module drives the LED with a 16-bit resolution. Due to the high PWM resolution, the RGB LED color is changed smoothly.

2.3 RGB LED diagnostics

The RGB LED diagnostic module reports actual LED average current calculated using the LED diode voltage values and applied PWM duty cycle.

The actual LED voltage is sampled by the ADC when the LED is turned ON, approximately 2 µs for red, 4 µs for green, and 6 µs for the blue diode after the PWM signal falling edge. The sampled value is used to calculate the diode resistor voltage. As the resistor voltage and its resistance is known, the diode peak current is calculated. The average current value is calculated using the known PWM duty cycle value and diode peak current.

The calculation is carried out in 16-bit fractional arithmetic using the AMMCLIB [3].

2.4 LIN Slave node position detection

The on-board LIN switch hardware is designed to support LIN Slave node auto-addressing and daisy-chaining, see Figure 3. The LIN_IN and LIN_OUT LIN signal lines are either connected or disconnected based on the MCU PS0 output pin logic level, see Table 2.

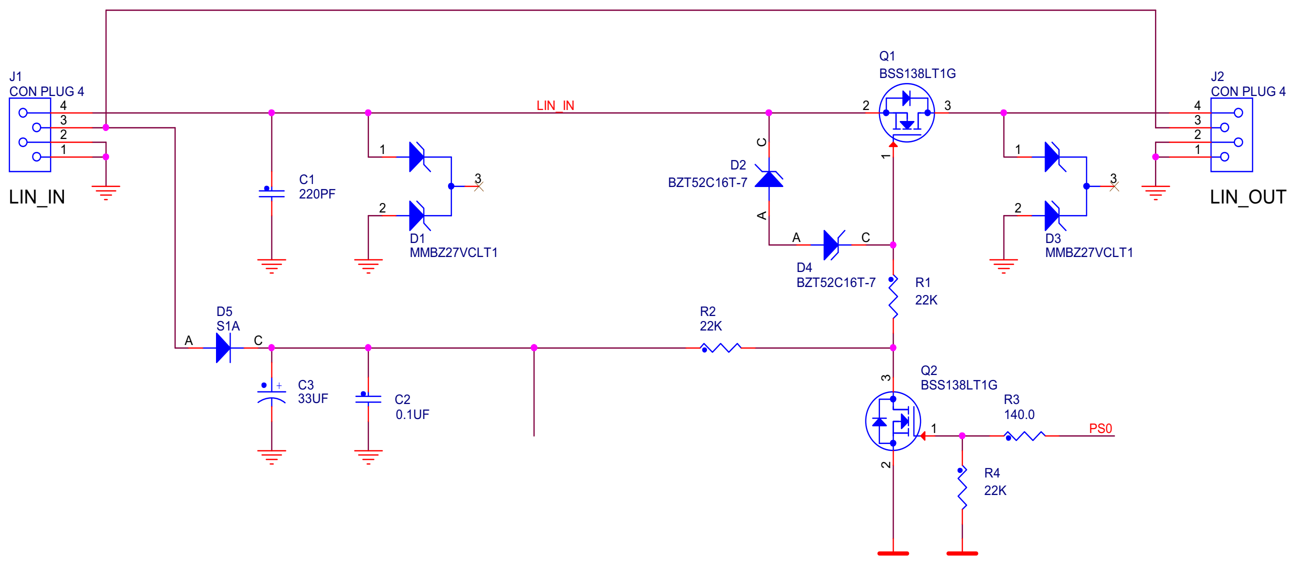

Figure 3. LIN signal line switch

When the system is powered-up, the LIN_IN (J1) and LIN_OUT (J2) LIN signal lines (pin 4) are disconnected. The LIN Master unit communicates to the closest LIN Slave unit only. The LIN Master unit sends the LIN configuration frame. Once the LIN Slave address is configured, the LIN_IN and LIN_OUT node LIN signal lines are connected and the LIN Slave configuration is repeated for the following node in the line. The cycle is repeated until the configuration of the LIN network slaves is not finished.

Table 2. LIN signal line switch control

MCU PS0 pin	LIN_IN and LIN_OUT
High level	Disconnected
Low level	Connected

3 MC9S12ZVL32 modules configuration

The RGB LED lighting application uses the following set of peripheral modules:

1. Clock, Reset and Power Management Unit (CMPU)
2. Timer module (TIM)
3. Pulse Width Modulator (PWM)
4. Analog-to-Digital Converter (ADC)
5. Port Integration Module (PIM)
6. Interrupt (INT)

The module's configuration and usage is described in the following chapters. Detailed information on the MCU modules can be found in the MC9S12ZVL32 reference manual [1].

The application software is developed to meet the following specification:

- RGB LED control
- RGB LED diagnostics
- FreeMASTER enabled

For detailed info see Section 4, RGB LED lighting application demo

3.1 Clock, Reset and Power Management Unit

The Clock, Reset and Power Management Unit (CMPU) sets the CPU clock to 64 MHz and the bus clock to 32 MHz using the Internal 1 MHz clock signal.

The Internal 1 MHz reference clock is selected as the source clock for the PLL (CPMUREFDIV_REFDIV = 0, CPMUREFDIV_REFFRQ = 0).

The PLL VCOCLK frequency is set to 64 MHz (CPMUSYNR_SYNDIV = 31):

$$VCOCLK = (2 \times (SYNDIV + 1)) \times 1MHz \quad \textit{Eqn. 1}$$

The VCOCLK signal frequency is divided by 1 (CPMUPOSTDIV_POSTDIV = 0). This is used as the 64 MHz core clock ECLK2X signal and the 32 MHz bus clock ECLK signal.

3.2 Timer Module

The TIM channel 0 is running as an application scheduler time base. The TIM channel 0 compare output is configured as no action on a channel compare event (TIM0TCTL2_OL0 = 0; TIM0TCTL2_OM0 = 0). The TIM channel 0 interrupt is enabled (TIM0TIE_C0I = 1).

The timer single tick is configured to 1 µs (TIM0TSCR2_PR = 5).

3.3 Pulse Width Modulator

The Pulse Width Modulator module controls the on-board RGB LED.

The PWM module channels operate in 16-bit resolution mode (PWMCTL_CON01 = 1, PWMCTL_CON23 = 1, PWMCTL_CON45 = 1, PWMCTL_CON67 = 1). The clock B is selected as PWM clock source. The PWM clock B equals 16 MHz (PWMPRCLK_PCKB = 1).

The channels PWM1, PWM3, PWM5 generate a 244 Hz PWM starting with low level polarity (PWMPOL1 = 0, PWMPOL3 = 0, PWMPOL5 = 0). The PWM1, PWM3, PWM5 channels are enabled (PWME_PWME1 = 1, PWME_PWME3 = 1, PWME_PWME5 = 1).

3.4 Analog-to-Digital Converter

An Analog-to-Digital Converter is used to sample RGB LED voltage.

The ADC clock is set to 8 MHz (ADC0TIM = 1). The ADC module is configured to access mode via data bus (ADC0CTL_0_ACC_CFG = 2). The ADC is running in trigger mode (ADC0CTL_0_MOD_CFG = 1) with 8-bit resolution (ADC0FMT_SRES = 0). The end-of-list interrupt is enabled (ADC0CONIE_1_EOL_IE = 1).

The ADC module samples LED voltage using a single command sequence list (ADC0CTL_1_CSL_BMOD = 0) and single result value list (ADC0CTL_1_RVL_BMOD = 0). The LED voltage is recalculated to LED average current, see Section 2.3 ,RGB LED diagnostics.

3.5 Port Integration Module

The Port Integration Module is used to drive the RGB LED, see Section 2.2 ,RGB LED control, and control the LIN switch, see Section 2.4, LIN Slave node position detection.

The port pins PT3, PT4, PT5 can be used to debug the application by enabling the LED_APPLICATION_DEBUG macro, see Table 3. The pins share the SCI and TIM modules as well.

Table 3. Application debug

MCU pin	LED_APPLICATION_DEBUG
PT3	TIM Ch0 interrupt
PT4	ADC end-of-list interrupt
PT5	PWM falling edge generated

3.6 Interrupt

The Interrupt module sets the interrupt priorities as follows, starting with the highest priority:

1. The ADC0 end-of-list - samples are ready for processing
2. The TIM channel 0 - 1 ms periodic interrupt used for application control
3. The PIM Port P - PWM module signal falling edge captured

4 RGB LED lighting application demo

The RGB LED lighting application demo can be built using the attached AN4842SW.zip file containing X-S12ZVL32-USLED board hardware and software files.

4.1 Hardware

The X-S12ZVL32-USLED board, see Figure 4, is built using the AN4842SW.zip hardware files. These files include the board schematic, bill of materials, gerber files and an instruction for board manufacturing.

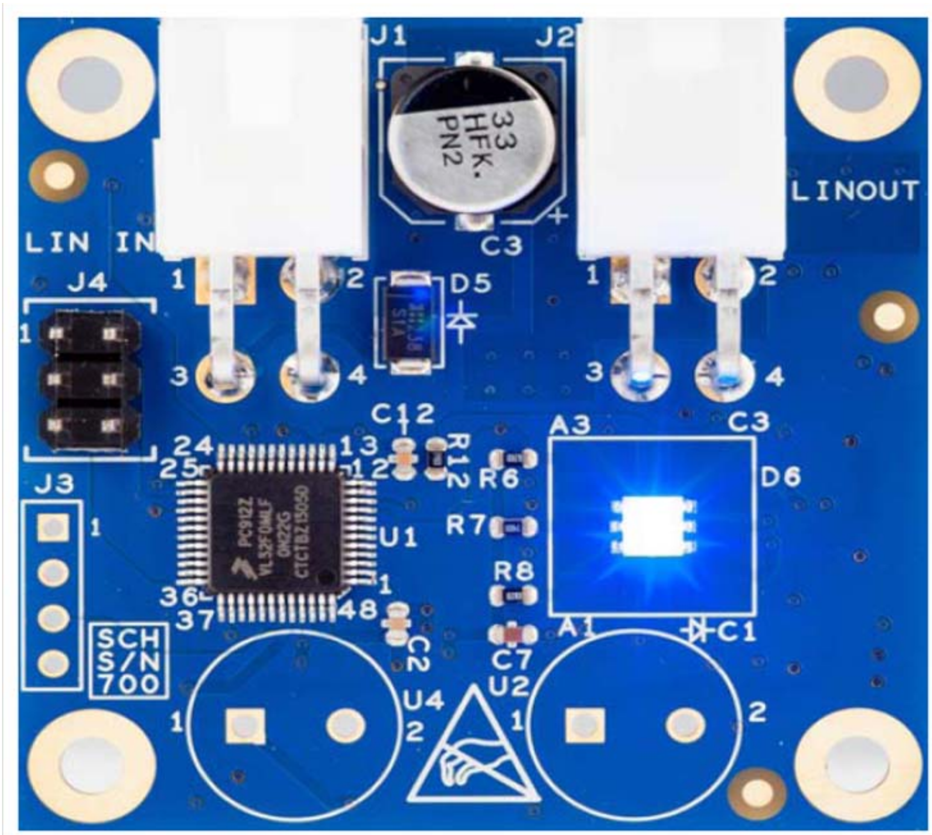

Figure 4. The X-S12ZVL32-USLED board

The X-S12ZVL32-USLED board contains, see Section Appendix A ,X-S12ZVL32-USLED board schematic:

- MC9S12ZVL32 LQFP32 MCU, see [1]
- LIN Slave node position detection hardware
- RGB LED, including diagnostics hardware
- Reverse battery protection
- BDM enabled
- Ultrasonic sensing circuitry (not used, not populated)

4.2 Software

The software files are packed as the MC9S12ZVL32_RGBLED_REV1.exe file available in AN4842SW.zip file. The application is developed using the CW10.3 environment. The MC9S12ZVL32_RGBLED_0N22G_AMMCLIB_v_1_0_0.elf file can be found in the project FLASH folder. For code download the P&E USB Multilink Interface is used.

The RGB LED lighting application demo shows:

- RGB LED color control
- RGB LED diagnostics
- FreeMASTER tool:
  - RGB LED control
  - RGB LED average current display
- Integrating the AMMCLIB [3].

4.3 Demo set-up

The demo set-up is depicted in Figure 5. The demo is designed to be able to run either with or without the FreeMASTER tool.

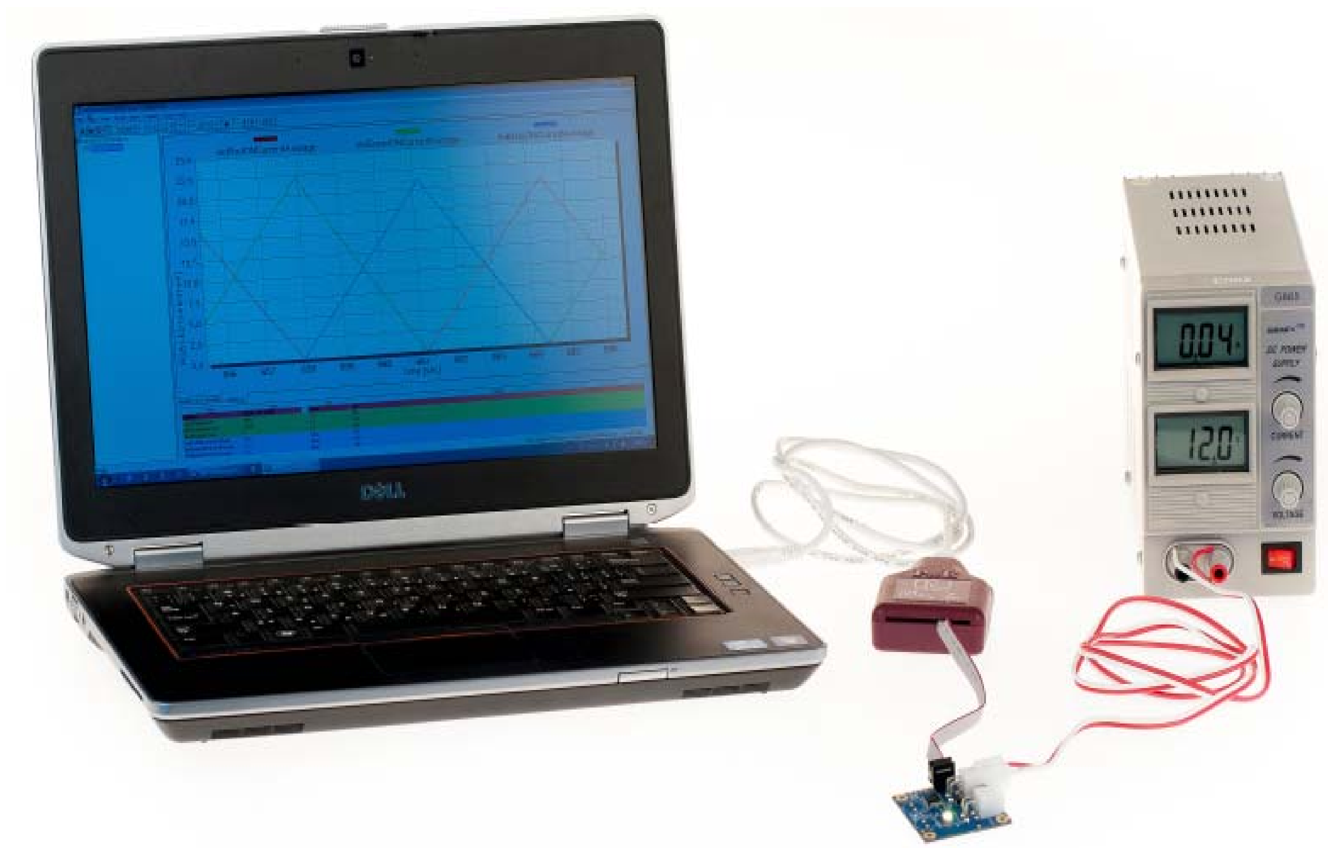

Figure 5. Demo set-up

Follow the instructions for a complete demo set-up:

1. Install the FreeMASTER tool [2] on the PC used
2. Connect the +12 V/100 mA DC power supply to the X-S12ZVL32-USLED board at J1, LIN_IN:
   a GND to J1 pin 1
   b +12 V to J1 pin 3
3. Turn ON the power supply
4. Connect the P&E USB Multilink Interface to the X-S12ZVL32-USLED board at J4
5. Open the ‚MC9S12ZVL32_RGBLED.pmp‚Äù file, available in the AN4842SW.zip file
6. Go to the FreeMASTER file Project/Options folder and check the settings as depicted in Figure 6 and Figure 7
7. Run FreeMASTER communication by File/Start Communication
8. Control the RGB LED using FreeMASTER, see Figure 8:
   a RGBLED_OFF - RGB LED is OFF
   b RGBLED_ON_MANUAL - RGB LED is controlled by FreeMASTER variables redLEDdutyCycle, greenLEDdutyCycle and blueLEDdutyCycle. Enter a number in the range of 0 to 65535.
   c RGBLED_ON_DEMO - RGB LED color is changed automatically. This is the demo default mode after the module power-on.
9. The RGB LED average current is displayed on the FreeMASTER page, see Figure 8

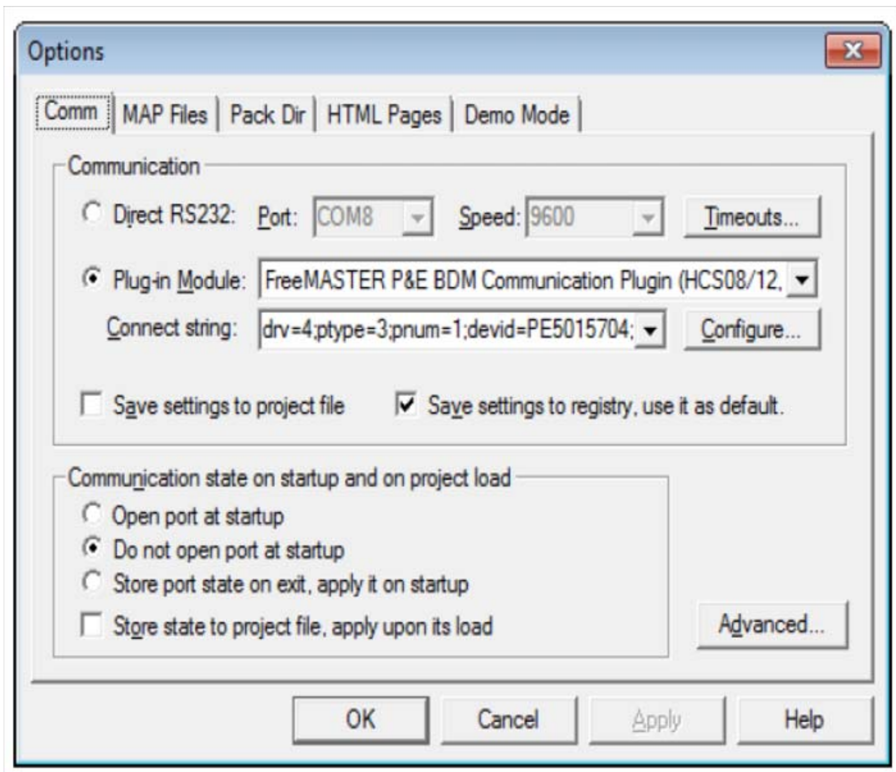

Figure 6. FreeMASTER Communication configuration

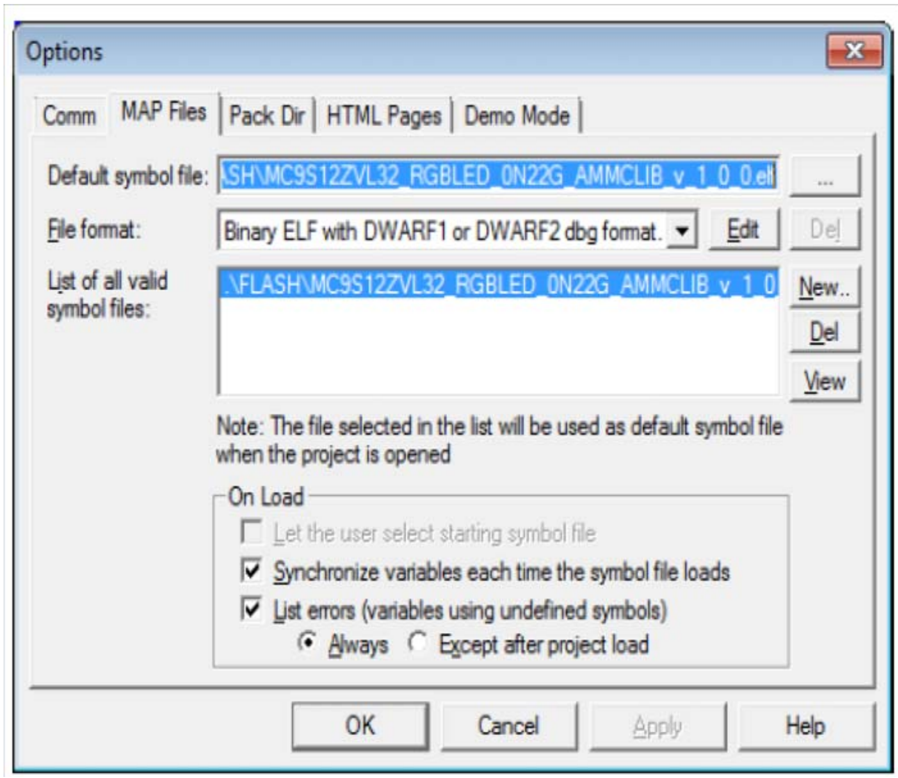

Figure 7. FreeMASTER MAP Files configuration

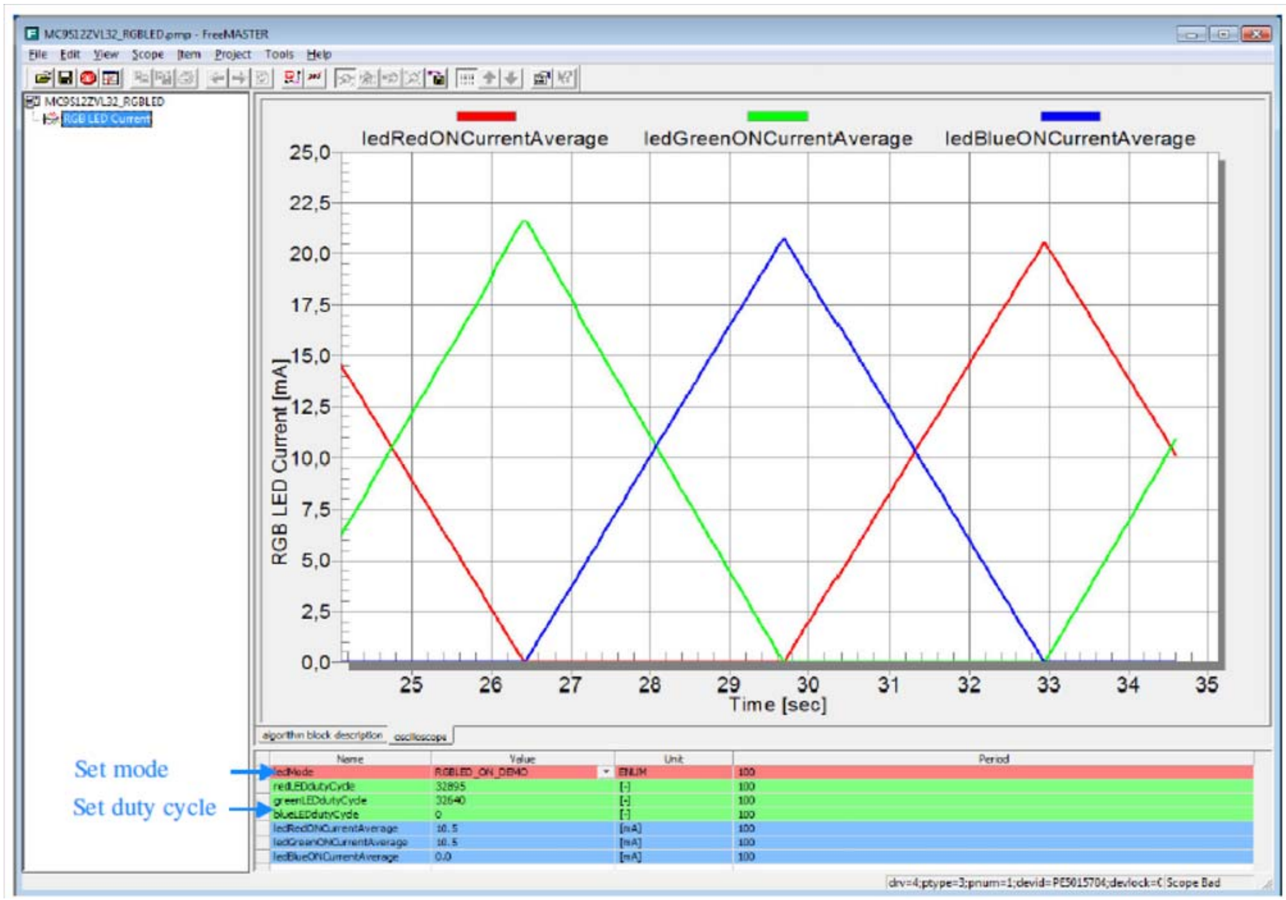

Figure 8. FreeMASTER RGB LED control page

5 References

1. MC9S12ZVL Family Reference Manual, available at freescale.com
2. FreeMASTER Run-Time Debugging Tool, available at freescale.com/freemaster
3. Automotive Math and Motor Control Library Set, available at freescale.com/AutoMCLib

6 Acronyms

ADC	Analog-to-Digital Converter
BDM	Background Debug Module
CMPU	Clock, Reset and Power Management Unit
DC	Direct Current
HVI	High Voltage Input
INT	Interrupt
ISR	Interrupt Service Routine
LIN	Local Interconnect Network
MCU	Microcontroller Unit
PC	Personal Computer
PIM	Port Integration Module
PWM	Pulse Width Modulation
RGB LED	Red, Green, Blue Light Emitting Diode
TIM	Timer Module
USB	Universal Serial Bus
VSUP	Voltage Supply

Appendix A X-S12ZVL32-USLED board schematic

For this schematic, please refer to “LIN_Daisy_Chain_Switch_LEDs.pdf”, attached with the pdf of this Application Note.

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Document Number: AN4842
Rev. 1.0
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