APPLICATION NOTE

AT03201: 100W Commercial LED Light with Wireless Connection - Hardware User Guide

Atmel AVR XMEGA

Description

The reference design kit of 100W Commercial LED Light with Wireless Connection is developed to demonstrate Lightweight Mesh (LwMesh) protocol function based on the Atmel® AVR® ATmega256RFR2. The hardware includes three parts, AC to DC power supply, Atmel single-chip RF MCU Control board, and LED drive circuit based on Atmel AVR ATxmega8E5. The LED string is controlled by PC software via the Lightweight Mesh protocol commands through the ATmega256RFR2. The kit supports to LED on/off, and tunable brightness.

For this reference design, the hardware design files (schematic, BOM, and PCB Gerber) and software source code can be downloaded from Atmel website. The provided hardware documentation can be used with no limitations to manufacture the reference hardware solution for the design.

Features

- Atmel AVR ATmega256RFR2 Microcontroller with 2.4GHz radio transceiver
- Atmel AVR ATxmega8E5 Microcontroller
- Drives four high power LED strings
- Up to 750mA current for each LED string with individual PWM
- Wide PWM dimming range with 16-bit solution
- Open and short LED string protection
- Replaceable LED strings
- 140W AC to DC power supply
- Time-dependent control for LED string
- One button for user
- One dual LED for user
- Program/Debug interface: JTAG, PDI

Figure 1. 100W Commercial LED Light with Wireless Connection

1 Related Items

The following list contains links to the most relevant documents for the 100W Commercial LED Light with Wireless Connection.

- Atmel MCU Wireless ATmega256RFR2/ ATmega128RFR2/ ATmega64RFR2 Summary Datasheet
  The document contains complete and detailed description of all modules included in the Atmel MCU wireless microcontroller family.
- Atmel MCU Wireless ATmega256RFR2/ ATmega128RFR2/ ATmega64RFR2 Datasheet
  ATmega256RFR2 is the microcontroller used in this solution.
- Atmel AVR10004: RCB256RFR2 – Hardware User Manual
  The document describes the usage, design, and layout of the Atmel ATmega256RFR2 radio controller board.
- ATxmega32E5/ ATxmega16E5/ ATxmega8E5 Preliminary Datasheet
  ATxmega8E5 is the microcontroller used in this solution.
- Atmel AVR XMEGA® MANUAL
  The document contains complete and detailed description of all modules included in the Atmel AVR XMEGA E microcontroller family.
- AVR1612: PDI programming driver
  The Program and Debug Interface (PDI) is an Atmel proprietary interface for external programming and on-chip debugging of the device. This application note describes how to implement PDI programming.
- Atmel Studio 6
  Atmel Studio 6 is a free Atmel IDE for development of C/C++ and assembler code for Atmel microcontrollers.
- Atmel JTAGICE3
  JTAGICE3 is a mid-range development tool for Atmel AVR 8- and 32-bit microcontrollers with on-chip debugging for source level symbolic debugging, Nano Trace (if supported by the device) and device programming.

2 Overview

The Atmel AVR 100W Commercial LED Light with Wireless Connection kit is intended to demonstrate the Atmel AVR ATmega256RFR2 single-chip microcontroller and radio transceiver which is used in the LED Lighting application via Lightweight Mesh protocol; the two Atmel AVR ATxmega8E5 devices are used as the LED driver. The ATmega256RFR2 communicate with ATxmega8E5 via TWI bus.

The kit can drive four individual parallel high power LED Strings. Each String can output 850mA under 38V, so the general output power can reach over 100W. The LED string can be controlled individually by PWM signal; it can easily realize the on/off and tunable brightness. The control commands come from the PC software via wireless communication.

The kit includes three boards: Power Supply Board, MCU Control Board, and LED Drive Board.

Power Supply Board contains two AC to DC switching power supplies, one dedicates for four parallel high power LED strings, and it provides 40V up to 3.5A. Another is standby power for MCUs, and it provides 12V/100mA and -6V/20mA.

MCU Control Board contains the MCU ATmega256RFR2, RF signal amplifier, antenna, 8-megabit data flash, and trickle charge timekeeping chip. The ATmega256RFR2 in charge of the communication between the kit and PC software, and communicate with the LED Driver board to control the LED String by TWI bus.

LED Driver Board is configured as two ATxmega8E5 devices, and four parallel LED drive circuits. The four LED Strings divided into two groups, one ATxmega8E5 control two of them.

Figure 2-1 shows the available features on the MCU control board.

Figure 2-1. Overview of the MCU Control Board of the Kit

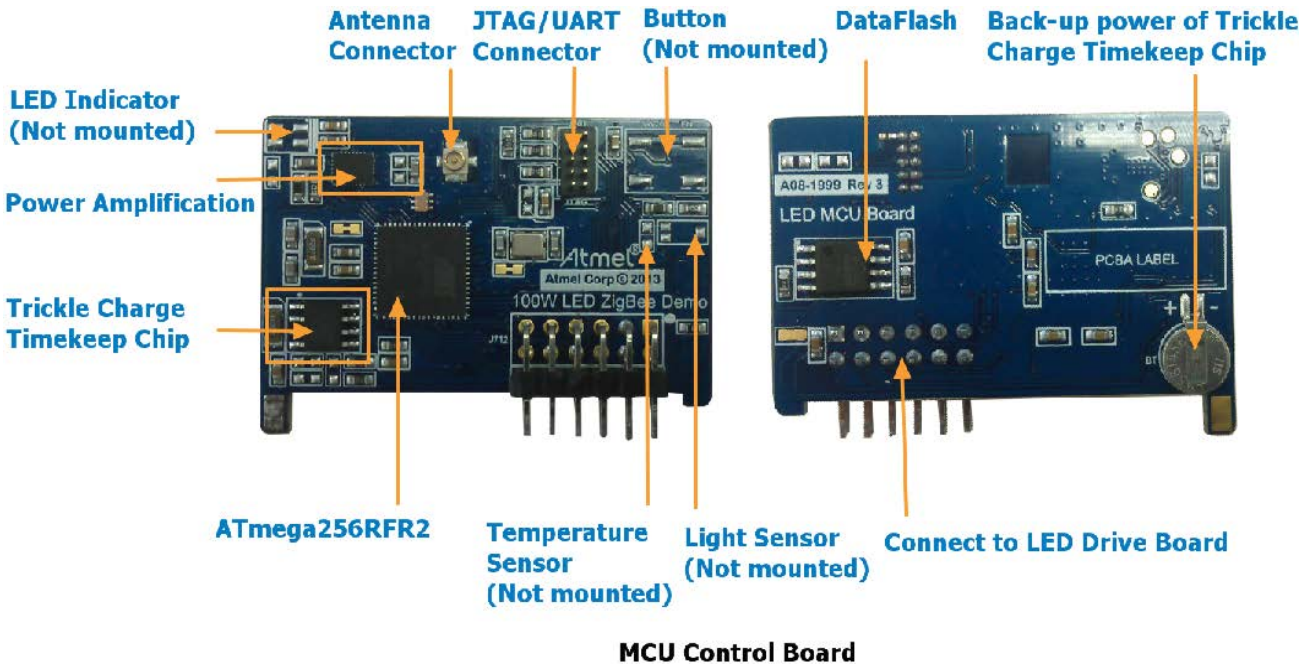


Figure 2-2 shows the available features on the LED Drive board.

Figure 2-2. Overview of the LED Drive Board of the Kit

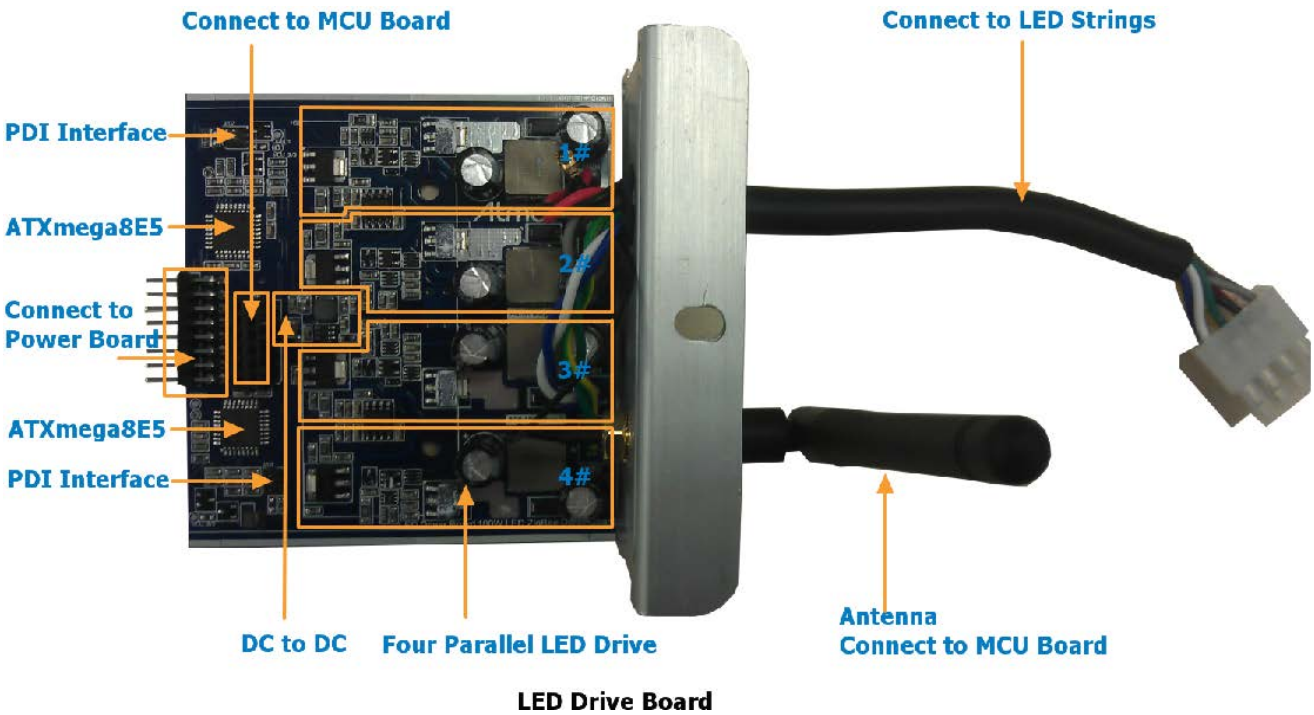
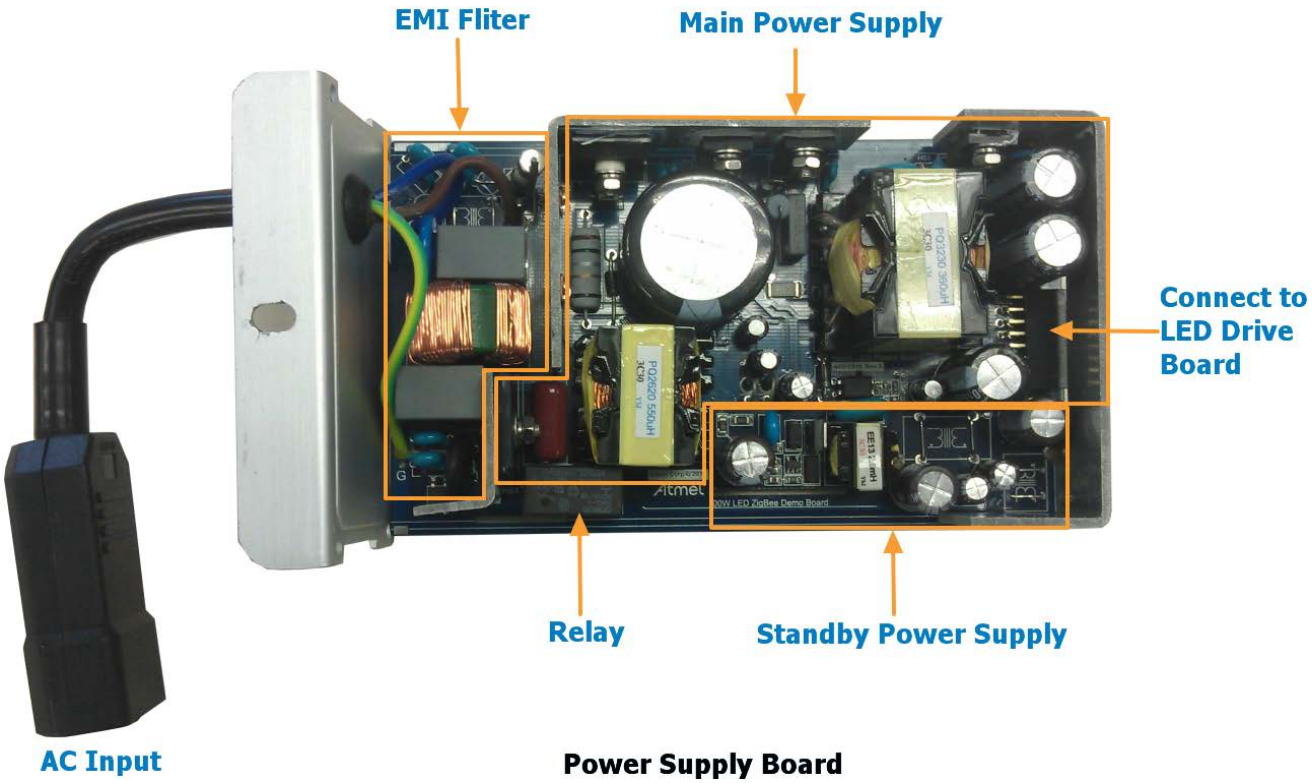


Figure 2-3 shows the available features on the Power Supply board.

Figure 2-3. Overview of the Power Supply Board of the Kit



2.1 Components for Setup

The components in Table 2-1 are necessary to perform all functions of the kit.

Table 2-1. Components for Kit Setup

Component	Function
Kit	The kit assembled with Power Supply Board, MCU Control Board, and LED Driver Board
AC Power line	Supply 110V/220VAC and 50/60Hz frequency power to the kit
Four LED Strings If=1A, 28V≤Vf≤38V@If=1A	As a load for kit
Programming Tool with JTAG and PDI interface	Debug and Programming
ZLL/Ethernet Gateway	Communicate the kit and Wi-Fi Router
Wi-Fi Router	Communicate the Tablet or Smartphone and ZLL/Ethernet Gateway
Personal Computer	Control the kit using Personal Computer software
Application Software	Running on the Personal Computer to control the kit

2.2 Programming Firmware

The Atmel ATmega256RFR2 and ATxmega8E5 on the kit are programmed with the default firmware. The detailed description of the firmware is available in the Atmel AT06700: LED Commercial Light Kit and Gateway Software User Manual.

2.3 Power Supply

The kit is powered by AC line under the voltage range 85V to 264V with 50/60Hz frequency. The AC to DC switching power supply can deliver 40V/3.5A, 12V/100mA, and -6V/20mA.

The 40V supplies to LED strings. The 12V and -6V supply power to LED driver circuit. The 12V is also regulated down to 3.3V by an onboard DC-DC regulator, which provides power to the MCUs on MCU Control Board and LED Drive Board.

Note: In this application, the ATxmega8E5 devices are running under 32MHz, according to the datasheet of the ATxmega8E5, the V_{CC} of ATxmega8E5 needs greater than 2.7V.

2.4 Programming the Kit

The ATmega256RFR2 on the kit can be programmed by programming tools through the JTAG interface.

The ATxmega8E5 on the kit can be programmed through the PDI interface.

3 Connectors

The 100W Commercial LED Light with Wireless Connection kit has several connectors and headers which dedicate for difference purpose, shown in Table 3-1.

Table 3-1. Connector and Functions

Connector	Function
J701	JTAG/UART interface for programming and debug
J702,J703	PDI interface for programming and debug
J704, J705	Connector between the Power Supply Board and LED Driver Board
J706, J712	Connector the LED Driver Board and MCU Board
J707	AC source connector
CN401,CN402,CN501,CN502	LED Strings Connector

3.1 JTAG/UART Header

The Atmel AVR ATmega256RFR2 can be programmed and debugged via JTAG interface. Any tools which carry the JTAG interface can program and debug the kit. JTAGICE3 is recommended for programming. The definition of the JTAG interface can be found in Table 3-2.

Table 3-2. AVR ATmega256RFR2 Programming and Debugging Interface – JTAG

Pin on programming header	Pin on AVR ATmega256RFR2	JTAG
1	PF4	TCK
2	-	GND
3	PF6	TDO
4	-	VCC
5	PF5	TMS
6	RSTN	nSRST
7	-	-
8	-	-
9	PF7	TDI
10	-	GND

The definition of the UART interface can be found in Table 3-3.

Table 3-3. AVR ATmega256RFR2 Universal Asynchronous Receiver/Transmitter Interface – UART

Pin on programming header	Pin on AVR ATmega256RFR2	UART
1	-	-
2	-	GND
3	-	-

Pin on programming header	Pin on AVR ATmega256RFR2	UART
4	-	VCC
5	-	-
6	-	-
7	PE0	RXD
8	PE1	TXD
9	-	-
10	-	-

The JTAG and UART interface uses the different pins at the same header J701.

3.2 PDI Header

The Atmel AVR ATxmega8E5 devices can be programmed and debugged via PDI header. Any tools which carry the PDI interface can program and debug the kit. JTAGICE3 is recommended for programming. The definition of the PDI interface can be found in Table 3-4.

Table 3-4. AVR ATxmega8E5 Programming and Debugging Interface – PDI

Pin on programming header	PDI
1	DATA
2	V_{CC}
3	-
4	-
5	CLK
6	GND

3.3 Connector between the Power Supply Board and LED Driver Board

The female connector J704 is lie on the Power Supply Board. The male J705 is lie on the LED Driver Board. The Power Supply Board provides the power to the LED Driver Board via the connector pair.

Table 3-5. Connector between Power Supply Board and LED Driver Board

Pin on J704	Pin on J705	Name on the connector
1	16	-
2	15	-
3	14	-12VDC
4	13	Control the relay ON or OFF
5	12	+12VDC
6	11	-
7	10	GND for DC to DC circuit
8	9	-

Pin on J704	Pin on J705	Name on the connector
9	8	Power GND
10	7	Power GND
11	6	+40VDC
12	5	+40VDC
13	4	+40VDC
14	3	+40VDC
15	2	Power GND
16	1	Power GND

3.4 Connector between the LED Driver Board and MCU Board

The male connector J712 is lie on the MCU Board. The J706 on the LED Drive Board needs to assemble any connector into it. The J712 connector plugs into J706 to achieve connect between the LED Driver Board and MCU Board.

Table 3-6. Connector between LED Driver Board and MCU Board

Pin on J706	Pin on J712	Name on the connector
1	11	GND
2	12	TWI_SCL
3	9	VIN_3V3
4	10	TWI_SDA
5	7	-
6	8	-
7	5	-
8	6	-
9	3	-
10	4	-
11	1	-
12	2	Control the Relay ON or OFF

3.5 LED Strings Connector

The CN401, CN402, CN501, and CN502 are LED strings connectors. These connectors are polarity sensitive.

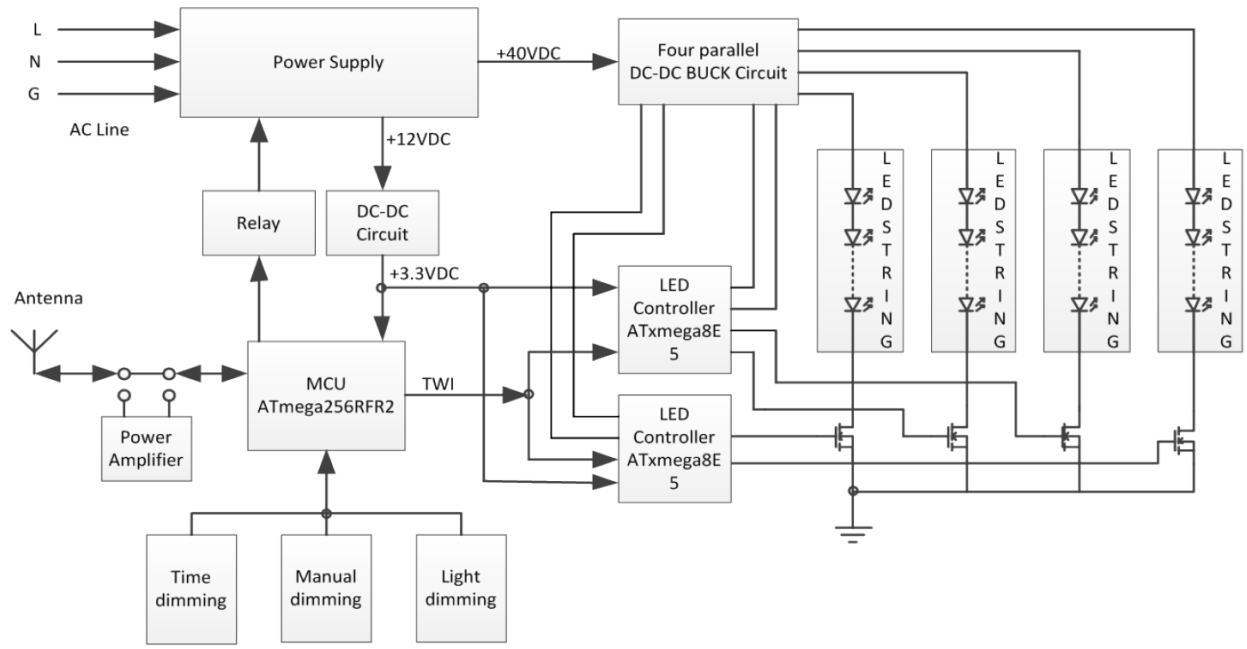
Table 3-7. LED Strings Connector

Pin on LED Strings Connector	Name on LED Strings Connector
1	LED String+
2	LED String-

4 Peripherals

Figure 4-1 shows the system block diagram of the 100W Commercial LED Light with Wireless Connection kit.

Figure 4-1. 100W Commercial LED Light with Wireless Connection System Block Diagram



WARNING

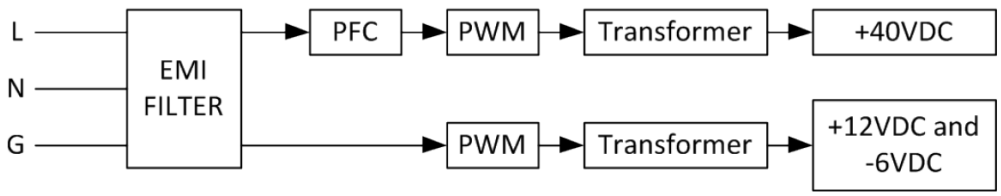
The kit has high voltages on the board that can pose a shock hazard to the user. Appropriate care should be taken when operating the board. In addition to the high power LED strings are used to LED Load. Do not look directly at the LED strings when the kit is active and/or protect your eyes with dark glasses since the LED strings are very bright.

To turn on the kit, simply plug the power cord into an AC socket which applies the 85V to 264V and 50/60Hz frequency power source. The LED strings will light up while the kit is powered.

4.1 AC to DC Switching Power Supply

In the system, there are two AC to DC switching power supplies. One is dedicate for LED strings, and the other is standby power supply for MCUs. The standby power supply is used for getting low static power (low than 0.3W). These two power supplies share one filter circuit. Figure 4-2 shows the diagram of the AC to DC switching power supply.

Figure 4-2. AC to DC Power Supply System Block Diagram



The main power supply contains the Power Factor Correction (PFC) circuit, device FA5612 works as the PFC converter in this application which makes the power factor value better than 99% with the rated load and rated input AC voltage. The rectification voltage of the AC input voltage will boost to 400VDC.

The FA5641 is a quasi-resonant type switching power supply control IC with excellent standby-by characteristics. The main power supply uses a secondary-side control technology by opto-isolated feedback for getting precise output voltage. It also works at the fixed-frequency Discontinuous Conduction Mode operation at heavy load, and switches to variable frequency operation at light load for obtaining maximum efficiency.

The main power supply provides 40V/3.5A for LED Strings, and input voltage range is 85V to 264VAC with 50/60Hz frequency. The efficiency is more than 89% with the rated output load and rated input AC voltage.

About the standby power supply, the iw1706 is used to PWM controller. The standby power supply uses a primary-side control technology to eliminate the opto-isolated feedback and secondary regulation circuits required in traditional designs.

The standby power supply works at the fixed-frequency Discontinuous Conduction Mode (DCM) under heavy load, and switches to variable frequency operation under light load to get the maximum efficiency. In other words, it uses adaptive multi-mode PWM/PFM control to dynamically change the BJT switching frequency for efficiency and EMI.

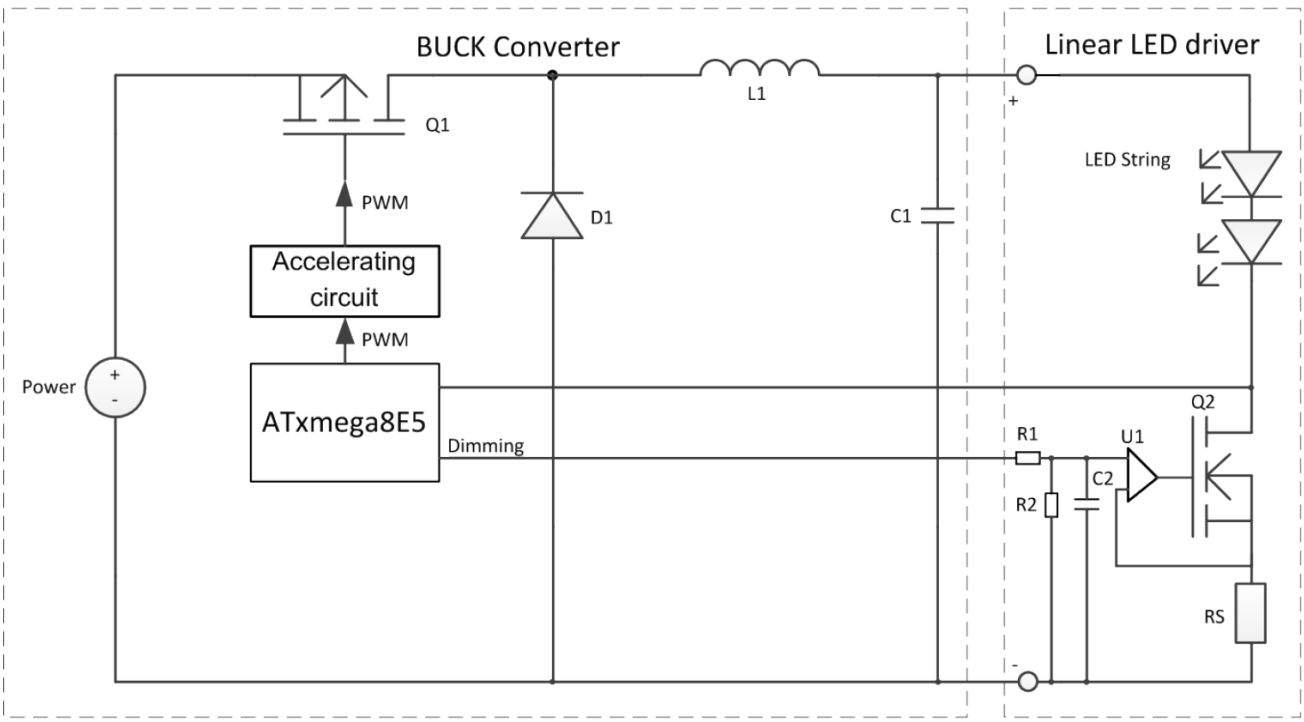
The standby power supply provides 12V/100mA and -6V/20mA for system.

The main power supply and standby power supply are also build-in fault protection features include overvoltage protection (OVP), output short circuit protection (SCP), and over-current protection (OCP).

4.2 BUCK LED Driver

Buck converter and linear driver are used to drive LED strings. Figure 4-3 shows the diagram of the BUCK LED driver.

Figure 4-3. Diagram of BUCK LED Driver



In the Buck converter, the Atmel ATxmega8E5 MCU generates the fixed 50kHz PWM to drive Q1 MOSFET, and the Buck converter output proper voltage for LED string. When MCU detected the voltage at the Drain of the Q2

more than 0.3V, the MCU will immediately turn off the PWM signal, and then turn off the Q1 MOSFET. So the voltage of the C1 will turn down until the voltage at the Drain of the Q2 less than 0.3V and then turn on Q1 MOSFET to provide power for LED string. This process is immediately achieved by on-chip hardware modules - linking the Event System Controller module to the Fault Extension module in the Atmel ATxmega8E5.

In the Buck Converter circuit, the response speed of the Q1 MOSFET should be as fast as possible, and delay time should be as short as possible between the PWM output of the MCU and the drive of the Q1 MOSFET. So the accelerating circuit is needed in the BUCK Converter.

The linear driver is used to drive LED string current for dimming. The ATxmega8E5 MCU generates the fixed 60kHz PWM to drive external N-CH MOSFET Q2. The R1 and C2 consist of low pass filter. The U1 operational amplifier is consisted of negative feedback circuit. The R1 and R2 consisted of voltage division circuit. So the R1, R2, C2, U1, and Q2 consisted of the linear constant current source.

Suppose the value of the R_S and maximum current of the LED String, the user can turn the value of R1 and R2 to set the maximum current of the LED String from the hardware design. The relationship between the R1 and R2 as below:

$$I_{MAX} \times R_S = (V_{CC}/(R1+R2)) \times R2$$

After rearrange and substitute:

$$R1 = (V_{CC} \times R2)/(I_{MAX} \times R_S) - R2$$

I_{MAX} is the maximum current of the LED string. In the design, considering the type of the LED string used in this reference design, the I_{MAX} is set to be 850mA.

R_S is the sample resistance

V_{CC} is the power supply of the MCU device

In the design, considering the type of the LED string used in this reference design, the maximum LED string current is set to be 850mA, and suppose R_S is 0.15Ω. When MCU detected the voltage at the Source of the Q2 beyond 0.12V, the MCU will immediately turn off the Q2 MOSFET until the voltage at the Source of the Q2 less than 0.12V, then the ATxmega8E5 will turn on Q2 MOSFET again to provide power road for LED string.

Table 4-1. Buck Circuit PWM Connection

Pin on AVR ATxmega8E5	Buck Circuit PWM
PC5	PWM signal for one BUCK circuit
PC4	PWM signal for another BUCK circuit

Table 4-2. Linear Driver of the LED Connection

Pin on AVR ATxmega8E5	Linear Driver
PD4	PWM signal for one Linear constant current source
PD5	PWM signal for another Linear constant current source

Table 4-3. Measure Function in the Buck and Linear Driver Circuit Connection

Pin on AVR ATxmega8E5	Measure Function of the circuit
PA0	Measure the input voltage of another LED String
PA1	Measure the input voltage of one LED String

Pin on AVR ATxmega8E5	Measure Function of the circuit
PA3	Measure the output voltage of another LED String
PA4	Measure the output voltage of one LED String
PA5	Measure the current of one LED String
PD7	Measure the current of another LED String

The Atmel ATxmega8E5 device is debugged and programmed via PDI interface.

Table 4-4. PDI Interface Connection

Pin on AVR ATxmega8E5	PDI Header
PDI	PDI
/RESET	PCK

For more information about the buck circuit, see the application note Atmel AT04204: Design a Buck circuit with XMEGA E.

The ATxmega8E5 device communicates with ATmega256RFR2 via TWI bus.

Table 4-5. TWI Interface Connections

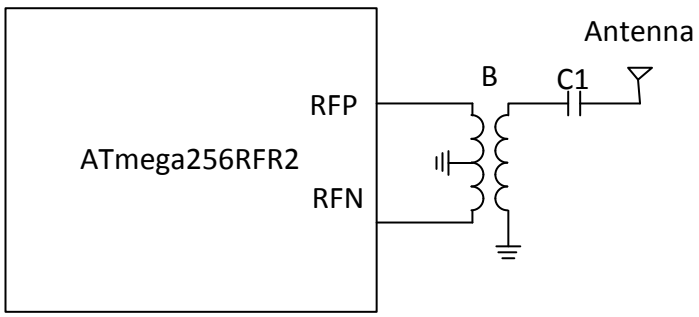
Pin on AVR ATxmega8E5	Pin on AVR ATmega256RFR2	TWI Interface
PC0	PD1	TWI_SDA
PC1	PD0	TWI_SCL

4.3 RF Transceiver

The Atmel AVR ATmega256RFR2 device integrates a high performance RF-CMOS 2.4GHz radio transceiver.

To get the RF function, only four components are needed; ATmega256RFR2, Balun, Capacitance, and Antenna.

Figure 4-4. RF Function Circuit



PCB layout is quite important for the high RF performance.

The application note Atmel AVR10004: RCB256RFR2 – Hardware User Manual will guide you how to design the RF PCB.

In order to expand transmission distance, a Power Amplifier (PA) circuit is added into the system. The user can choose whether to use the PA function via soldering cap C2, C3 and removing cap C1.

Figure 4-5. RF with PA Function Circuit

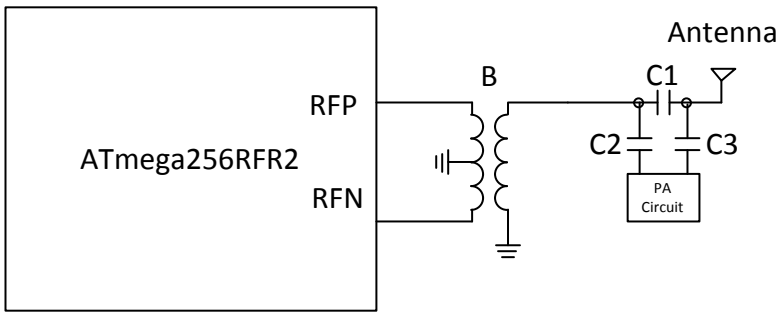


Table 4-6. Power Amplifier Connection

Pin on ATmega256RFR2	Power amplifier
PG0	CTX
PG1	ANT_SET
PG2	CPS
PD7	CSD

4.4 Trickle Charge Timekeep

In this reference design, use the DS1302 trickle charge timekeeping chip to wake up the Atmel ATmega256RFR2 when it is under the sleeping by time. It provides seconds, minutes, hours, days, date, month, and year information to ATmega256RFR2. The DS1302 has dual power for primary and back-up power supplies. The battery is used to back-up power, and it can be charged by primary power while the kit is working. DS1302 communicates with the ATmega256RFR2 via a simple serial interface.

Table 4-7. Simple Serial Interface Connection

Pin on DS1302	Pin on AVR ATmega256RFR2
SCLK	PD4
I/O	PD5
CE	PD6

4.5 DataFlash

The Serial Peripheral Interface (SPI) sequential access flash memory Atmel AT45DB081D is optional for user to storing any application data needed.

Table 4-8. Serial Peripheral Interface Connection

Pin on AVR ATmega256RFR2	Simple serial interface
PB0	SSN
PB1	SCK
PB2	MOSI

Pin on AVR ATmega256RFR2	Simple serial interface
PB3	MISO
RSTN	nRST

4.6 Function Button (not mounted)

The design is equipped with one function button for user.

Table 4-9. Function Button Connection

Pin on AVR ATmega256RFR2	Function Button
PE2	INT_BUTTON

4.7 LED Indicator (not mounted)

The design is equipped with one dual LED (Red and Green) available on the board that can be used to indicate the working condition of the kit. The green LED and the red LED can be individually activated by driving the connected I/O line to V_{CC}. The dual LED can also emit orange light when both red and green LEDs are activated.

Table 4-10. LED Connection

Pin on AVR ATxmega32E5	LED
PD2	Red LED
PD3	Green LED

4.8 Temperature Sensor (not mounted)

The design is equipped with one temperature sensor (NCP18WF104FR). The power is supplied by V_{CC} 3.3V. The ADC reference is 1.6V. R1 is series with the NTC to ensure the input voltage does not exceed the ADC input range.

The NTC sense voltage could be got from the following equation:

$$V_{SENSE} = (V_{CC} \times RTH1) \div (R1+RTH1)$$

For MCU, the equation for the ADC decimal code is:

$$ADC\ Code = 4095 \times (V_{SENSE} \div 1.6)$$

Figure 4-6. Temperature Sensor Circuit

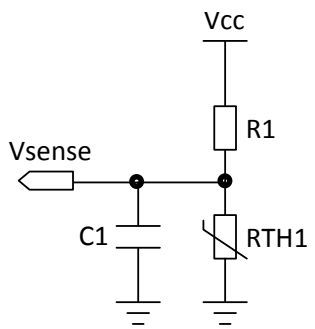


Table 4-11. NTC Table

Part number:	NCP18WF104F		
Resistance:	100kΩ ±1%		
B-constant:	4200k		
Temperature [°C]	Resistance [kΩ]	Temperature [°C]	Resistance [kΩ]
-40	4205.686	45	41.336
-35	2966.436	50	33.628
-30	2118.789	55	27.510
-25	1531.319	60	22.621
-20	1118.422	65	18.692
-15	825.570	70	15.525
-10	615.526	75	12.947
-5	463.104	80	10.849
0	351.706	85	9.129
5	269.305	90	7.713
10	207.891	95	6.546
15	161.722	100	5.572
20	126.723	105	4.764
25	100.000	110	4.087
30	79.222	115	3.518
35	63.509	120	3.040
40	51.084	125	2.634

Table 4-12. Temperature Sensor Connection

Pin on AVR ATxmega256RFR2	Temperature sensor
PF1	NTC_SENSE

The design is equipped with one light sensor TEMT6000. Thermostat can enable or disable the backlight based on the ambient light strength. The ADC reference is internal 1.6V.

The sense voltage can be found from the following equation:

$$V_{SENSE} = I_{CA} \times 10^{-6} \times R1$$

I_{CA} is Collector Light Current.

Figure 4-7. Light Sensor Circuit

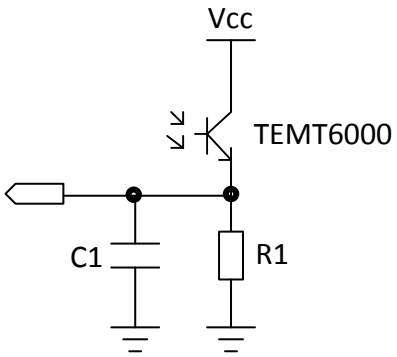


Figure 4-8. The Curve of Collector Light Current vs. Ambient Illuminance

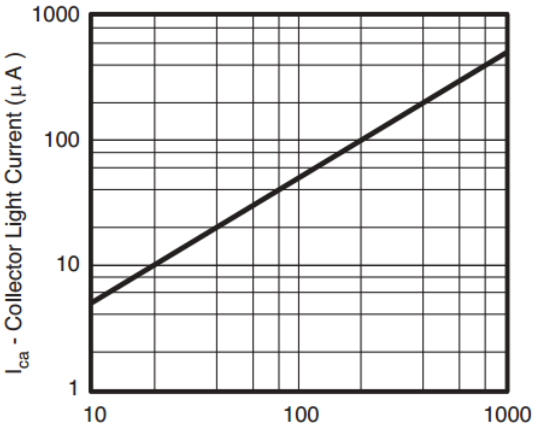


Table 4-13. The Sense Voltage vs. Illuminance

Illuminance [lx]	Current [µA]	V_{SENSE} [V]	Illuminance [lx]	Current [µA]	V_{SENSE} [V]	Illuminance [lx]	Current [µA]	V_{SENSE} [V]
10	5.0	0.050	75	37.5	0.375	140	70.0	0.700
15	7.5	0.075	80	40.0	0.400	145	72.5	0.725
20	10.0	0.100	85	42.5	0.425	150	75.0	0.750
25	12.5	0.125	90	45.0	0.450	155	77.5	0.775
30	15.0	0.150	95	47.5	0.475	160	80.0	0.800
35	17.5	0.175	100	50.0	0.500	165	82.5	0.825
40	20.0	0.200	105	52.5	0.525	170	85.0	0.850
45	22.5	0.225	110	55.0	0.550	175	87.5	0.875
50	25.0	0.250	115	57.5	0.575	180	90.0	0.900
55	27.5	0.275	120	60.0	0.600	185	92.5	0.925
60	30.0	0.300	125	62.5	0.625	190	95.0	0.950
65	32.5	0.325	130	65.0	0.650	195	97.5	0.975
70	35.0	0.350	135	67.5	0.675	200	100.0	1.000

Table 4-14. Temperature Sensor Connection

Pin on AVR ATxmega256RFR2	Light sensor
PF0	LIGHT_SENSE

4.9 LED String Power Control

In order to reduce the power consumption when turn off the LED Strings, the main switching power supply should be turn off.

Table 4-15. LED String Power Control Connection

Pin on AVR ATxmega256RFR2	LED String Power Control
PE7	LED_POWER_CT

5 Code Examples

The example application is based on the Atmel Software Framework that is included in Atmel Studio 6. The Atmel Software Framework can also be found as a separate package online at: http://www.atmel.com/tools/avrsoftwareframework.aspx.

For more information about the code example, see the application note Atmel AT06700: LED Commercial Light Kit and Gateway Software User Manual.

6 Revision History

Doc Rev.	Date	Comments
42302A	05/2014	Initial document release.

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