AND9505/D

LED Driver LC75760UJA Application Note

ON Semiconductor®

www.onsemi.com

APPLICATION NOTE

Features

- The LED Driver Outputs of Up to 12-ch can Drive LED Directly
  - Constant Current Output Form
  - Output Voltage: Absolute Maximum Rating 6.8 V; Maximum Operating Voltage 6.3 V
  - Output Current: Absolute Maximum Rating 60 mA; Maximum Operating Current 50 mA
  - Output Current Regulation Function (256 Steps)
  - Open/Short/Adjacent Outputs Short Detection Function
  - Slew Rate Limited Switching Function
- Serial Data Communication Supports 4-line Serial Format
  - Support 3.3 V and 5.0 V Operation
  - Maximum Operating Frequency 2 MHz
- Built-in 6-ch PWM Function for Brightness Adjustment of LED
  - Resolution of 128, 256, 512 or 1024 Steps
  - PWM Frame Frequency can be Controlled by Serial Data
- Built-in Thermal Protection Function (125°C: Automatic Adjustment of PWM, 150°C: Forced-off All LEDs)
- Provides the ERR Output Pin (125°C Temperature Abnormality, Open/Short/Adjacent Outputs Short Abnormality, LED Pull-up Supply Voltage Abnormality, External Resistance Abnormally, Fundamental Clock Abnormality, Reset Action)
- Provides a $\overline{\text{RES}}$ Pin and Built-in Voltage Detection Type Reset Circuit (VDET) for LSI Internal Initialization
- Switch of the Internal Oscillator Operating Mode and the External Clock Operating Mode can be Controlled by Serial Data
- Built-in Oscillator Circuit. (Built-in Resister and Capacitor for Oscillation)
- Built-in External Resistance Value Diagnosis Function for Constant Current

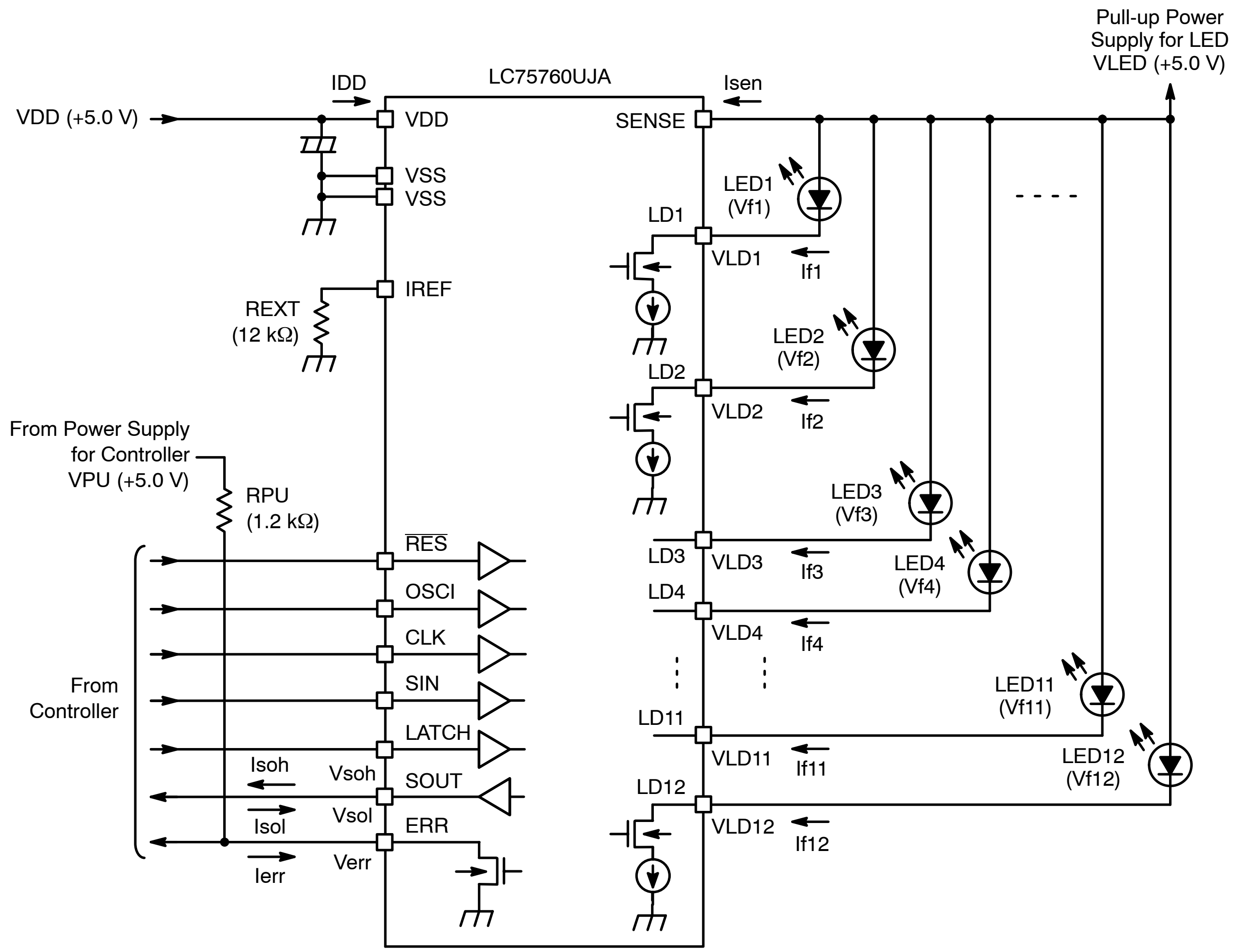
Typical Applications

- Automotive: Instrument Cluster, HVAC, Head Up Display
- Industry: Measurement Equipment

CALCULATION METHODS AND NOTES ABOUT THE POWER DISSIPATION

Application Sample 1

The following shows the calculation methods and note about the power dissipation when the constant current drive is performed without connecting a current limiting resistor to the LED driver output. This application sample is the simplest structure in this LSI and can achieve a system with minimum external parts. However, if the power dissipation is more than Pdmax of allowable power dissipation according to current value of LED driver outputs, please connect current limiting resistances to LED driver outputs and reduce the power dissipation to less than Pdmax.



NOTE:		
	VLD1 to VLD12:	Output low-level voltage from LD1 pin to LD12 pin.
	Vf1 to Vf12:	Forward voltage of LED connecting to LD12 pin from LD1 pin.
	If1 to If12:	Output current with PWM duty 100% from LD1 pin to LD12 pin. (LED forward current.)
	Isen:	Input current of SENSE pin.
	VLED:	Pull-up voltage of LED driver output.
	Verr:	Output low-level voltage of ERR pin.
	Ierr:	Output low-level current of ERR pin.
	Vsoh:	Output high-level voltage of SOUT pin.
	Isoh:	Output high-level current of SOUT pin.
	Vsol:	Output low-level voltage of SOUT pin.
	Isol:	Output low-level current of SOUT pin.
	VDD:	Supply voltage.
	IDD:	Current drain.

Figure 1. Schematic of Application Sample 1

The Figure 1 is shown when LEDs are driven by constant current without current limiting resistance connecting to LED drivers. The power dissipation in this case can be generated by the following calculation.

1. Power dissipation Pd_LED of LED driver outputs from LD1 pin to LD12 pin.
   Pd_LED =
   VLD1 × If1 × PWM duty +
   VLD2 × If2 × PWM duty +
   VLD3 × If3 × PWM duty +
   VLD4 × If4 × PWM duty +
   VLD5 × If5 × PWM duty +
   VLD6 × If6 × PWM duty +
   VLD7 × If7 × PWM duty +
   VLD8 × If8 × PWM duty +
   VLD9 × If9 × PWM duty +
   VLD10 × If10 × PWM duty +
   VLD11 × If11 × PWM duty +
   VLD12 × If12 × PWM duty =
   (VLED − Vf1) × If1 × PWM duty +
   (VLED − Vf2) × If2 × PWM duty +
   (VLED − Vf3) × If3 × PWM duty +
   (VLED − Vf4) × If4 × PWM duty +
   (VLED − Vf5) × If5 × PWM duty +
   (VLED − Vf6) × If6 × PWM duty +
   (VLED − Vf7) × If7 × PWM duty +
   (VLED − Vf8) × If8 × PWM duty +
   (VLED − Vf9) × If9 × PWM duty +
   (VLED − Vf10) × If10 PWM duty +
   (VLED − Vf11) × If11 × PWM duty +
   (VLED − Vf12) × If12 × PWM duty

2. Power dissipation Pd_SEN of SENSE pin.
   Pd_SEN = VLED × Isen

3. Power dissipation Pd_ERR of ERR pin.
   Pd_ERR = Verr × Ierr

4. Power dissipation Pd_SO of SOUT pin.
   Pd_SO = {(VDD − Vsoh) × Isoh + Vsol × Isol} / 2

5. Power dissipation Pd_VDD of VDD pin.
   Pd_VDD = VDD × IDD

Total power dissipation Pd of LC75760UJA has to be adjusted less than the allowable power dissipation Pdmax.

Pd = Pd_LED + Pd_SEN + Pd_ERR + Pd_SO + Pd_VDD < Pdmax

For example, in the case of electrical parameter such as the following condition, the power dissipation is the following.

1. Power dissipation Pd_LED of LED driver outputs from LD1 pin to LD12 pin.
   <Condition>
   VLED = 5.0 V, Vf1 to Vf4 = 2.0 V,
   Vf5 to Vf8 = 2.5 V, Vf9 to Vf12 = 3.0 V,
   If1 to If4 = 10 mA, If5 to If8 = 12 mA,
   If9 to If12 = 15 mA, PWM duty value from LD1 pin to LD12 pin are 100%.

   Pd_LED =
   (5.0 V − 2.0 V) × 10 mA × 100% +
   (5.0 V − 2.0 V) × 10 mA × 100% +
   (5.0 V − 2.0 V) × 10 mA × 100% +
   (5.0 V − 2.0 V) × 10 mA × 100% +
   (5.0 V − 2.5 V) × 12 mA × 100% +
   (5.0 V − 2.5 V) × 12 mA × 100% +
   (5.0 V − 2.5 V) × 12 mA × 100% +
   (5.0 V − 2.5 V) × 12 mA × 100% +
   (5.0 V − 3.0 V) × 15 mA × 100% +
   (5.0 V − 3.0 V) × 15 mA × 100% +
   (5.0 V − 3.0 V) × 15 mA × 100% +
   (5.0 V − 3.0 V) × 15 mA × 100% =
   30 mW × 4 + 30 mW × 4 + 30 mW × 4 = 360 mW

2. Power dissipation Pd_SEN of SENSE pin.
   <Condition>
   VLED = 5.0 V, Isen = 0.1 mA (= IIH3)
   Pd_SEN = 5.0 V × 0.1 mA = 0.5 mW

3. Power dissipation Pd_ERR of ERR pin.
   <Condition>
   Verr = 0.3 V (= VOL1), Ierr = 4 mA
   Pd_ERR = 0.3 V × 4 mA = 1.2 mW

4. Power dissipation Pd_SO of SOUT pin.
   <Condition>
   Vsoh = VDD − 0.3 V (= VOH1), Isoh = 4 mA,
   Vsol = 0.3 V (= VOL1), Isol = 4 mA
   Pd_SO = [{VDD − (VDD − 0.3 V)} × 4 mA + 0.3 × 4 mA] / 2 = 1.2 mW

5. Power dissipation Pd_VDD of VDD pin.
   <Condition>
   VDD = 5.0 V, IDD = 5 mA (= IDD2)
   Pd_VDD = 5.0 V × 5 mA = 25 mW

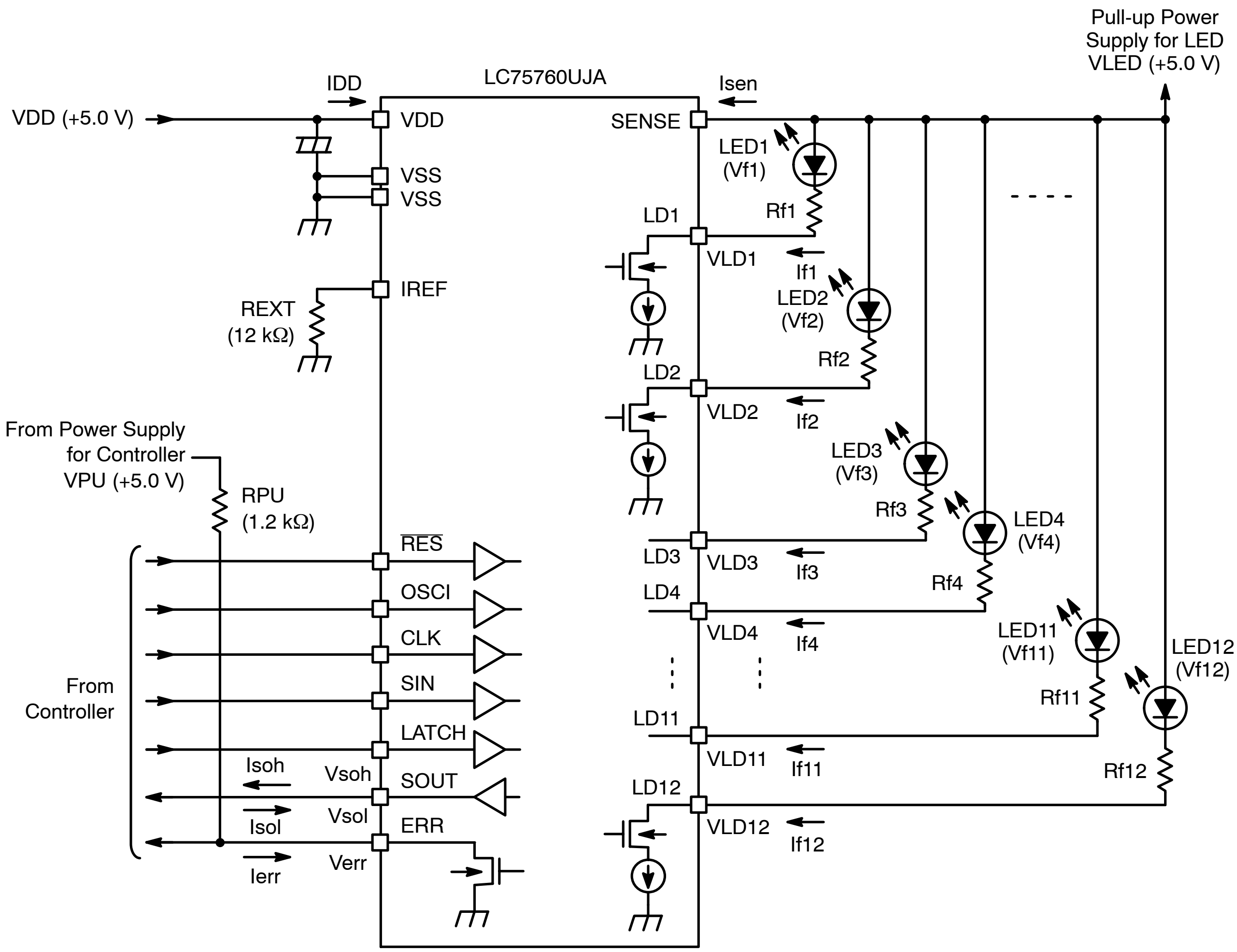
Total power dissipation Pd of LC75760UJA is the following.

Pd = 360 mW + 0.5 mW + 1.2 mW + 1.2 mW + 25 mW = 387.9 mW

The Pd is less than 430 mW of allowable power dissipation Pdmax, under T_A = 105°C operation on the glass-epoxy board of 76.2 mm × 114.3 mm × 1.6 mm with 2 layers. So the LSI can be operated under T_A = 105°C.

Application Sample 2

The following shows the calculation methods and note about the power dissipation when the constant current drive is performed with connecting a current limiting resistor to the LED driver output. This application sample is a circuit structure to improve the issue of when the power dissipation's Pd calculated by application sample 1 is more than allowable power dissipation's Pdmax. Please connect current limiting resistances between LED driver outputs and LED, and reduce the power dissipation to less than Pdmax.



NOTE:

VLD1 to VLD12:	Output low-level voltage from LD1 pin to LD12 pin.
Vf1 to Vf12:	Forward voltage of LED connecting to LD12 pin from LD1 pin.
If1 to If12:	Output current with PWM duty 100% from LD1 pin to LD12 pin. (LED forward current.)
Rf1 to Rf12:	Current limiting resistors connecting to LD12 pin from LD1 pin.
Isen:	Input current of SENSE pin.
VLED:	Pull-up voltage of LED driver output.
Verr:	Output low-level voltage of ERR pin.
Ierr:	Output low-level current of ERR pin.
Vsoh:	Output high-level voltage of SOUT pin.
Isoh:	Output high-level current of SOUT pin.
Vsol:	Output low-level voltage of SOUT pin.
Isol:	Output low-level current of SOUT pin.
VDD:	Supply voltage.
IDD:	Current drain.

Figure 2. Schematic of Application Sample 2

The Figure 2 is shown when LEDs are driven by constant current with current limiting resistance connecting to LED drivers. The power dissipation in this case can be generated by the following calculation.

1. Power dissipation Pd_LED of LED driver outputs from LD1 pin to LD12 pin.
   Pd_LED =
   VLD1 × If1 × PWM duty +
   VLD2 × If2 × PWM duty +
   VLD3 × If3 × PWM duty +
   VLD4 × If4 × PWM duty +
   VLD5 × If5 × PWM duty +
   VLD6 × If6 × PWM duty +
   VLD7 × If7 × PWM duty +
   VLD8 × If8 × PWM duty +
   VLD9 × If9 × PWM duty +
   VLD10 × If10 × PWM duty +
   VLD11 × If11 × PWM duty +
   VLD12 × If12 × PWM duty =
   (VLED − Vf1 − Rf1 × If1) × If1 × PWM duty +
   (VLED − Vf2 − Rf2 × If2) × If2 × PWM duty +
   (VLED − Vf3 − Rf3 × If3) × If3 × PWM duty +
   (VLED − Vf4 − Rf4 × If4) × If4 × PWM duty +
   (VLED − Vf5 − Rf5 × If5) × If5 × PWM duty +
   (VLED − Vf6 − Rf6 × If6) × If6 × PWM duty +
   (VLED − Vf7 − Rf7 × If7) × If7 × PWM duty +
   (VLED − Vf8 − Rf8 × If8) × If8 × PWM duty +
   (VLED − Vf9 − Rf9 × If9) × If9 × PWM duty +
   (VLED − Vf10 − Rf10 × If10) × If10 PWM duty +
   (VLED − Vf11 − Rf11 × If11) × If11 × PWM duty +
   (VLED − Vf12 − Rf12 × If12) × If12 × PWM duty

2. Power dissipation Pd_SEN of SENSE pin.
   Pd_SEN = VLED × Isen

3. Power dissipation Pd_ERR of ERR pin.
   Pd_ERR = Verr × Ierr

4. Power dissipation Pd_SO of SOUT pin.
   Pd_SO = {(VDD − Vsoh) × Isoh + Vsol × Isol} / 2

5. Power dissipation Pd_VDD of VDD pin.
   Pd_VDD = VDD × IDD

Total power dissipation Pd of LC75760UJA has to be adjusted less than the allowable power dissipation Pdmax.

Pd = Pd_LED + Pd_SEN + Pd_ERR + Pd_SO + Pd_VDD < Pdmax

For example, in the case of electrical parameter such as the following condition, the power dissipation is the following.

1. Power dissipation Pd_LED of LED driver outputs from LD1 pin to LD12 pin.
   <Condition>
   VLED = 5.0 V, Vf1 to Vf4 = 2.0 V,
   Vf5 to Vf8 = 2.5 V, Vf9 to Vf12 = 3.0 V,
   If1 to If4 = 20 mA, If5 to If8 = 30 mA,
   If9 to If12 = 40 mA, Rf1 to Rf4 = 100 Ω,
   Rf5 to Rf8 = 47 Ω, Rf9 to Rf12 = 27 Ω, PWM duty value from LD1 pin to LD12 pin are 100%.

   Pd_LED =
   (5.0 V − 2.0 V − 100 Ω × 20 mA) × 20 mA × 100% +
   (5.0 V − 2.0 V − 100 Ω × 20 mA) × 20 mA × 100% +
   (5.0 V − 2.0 V − 100 Ω × 20 mA) × 20 mA × 100% +
   (5.0 V − 2.0 V − 100 Ω × 20 mA) × 20 mA × 100% +
   (5.0 V − 2.5 V − 47 Ω × 30 mA) × 30 mA × 100% +
   (5.0 V − 2.5 V − 47 Ω × 30 mA) × 30 mA × 100% +
   (5.0 V − 2.5 V − 47 Ω × 30 mA) × 30 mA × 100% +
   (5.0 V − 2.5 V − 47 Ω × 30 mA) × 30 mA × 100% +
   (5.0 V − 3.0 V − 27 Ω × 40 mA) × 40 mA × 100% +
   (5.0 V − 3.0 V − 27 Ω × 40 mA) × 40 mA × 100% +
   (5.0 V − 3.0 V − 27 Ω × 40 mA) × 40 mA × 100% +
   (5.0 V − 3.0 V − 27 Ω × 40 mA) × 40 mA × 100% =
   20 mW × 4 + 32.7 mW × 4 + 36.8 mW × 4 = 358 mW

2. Power dissipation Pd_SEN of SENSE pin.
   <Condition>
   VLED = 5.0 V, Isen = 0.1 mA (= IIH3)
   Pd_SEN = 5.0 V × 0.1 mA = 0.5 mW

3. Power dissipation Pd_ERR of ERR pin.
   <Condition>
   Verr = 0.3 V (= VOL1), Ierr = 4 mA
   Pd_ERR = 0.3 V × 4 mA = 1.2 mW

4. Power dissipation Pd_SO of SOUT pin.
   <Condition>
   Vsoh = VDD − 0.3 V (= VOH1), Isoh = 4 mA,
   Vsol = 0.3 V (= VOL1), Isol = 4 mA
   Pd_SO = [{VDD – (VDD − 0.3 V)} × 4 mA + 0.3 × 4 mA] / 2 = 1.2 mW

5. Power dissipation Pd_VDD of VDD pin.
   <Condition>
   VDD = 5.0 V, IDD = 5 mA (= IDD2)
   Pd_VDD = 5.0 V × 5 mA = 25 mW

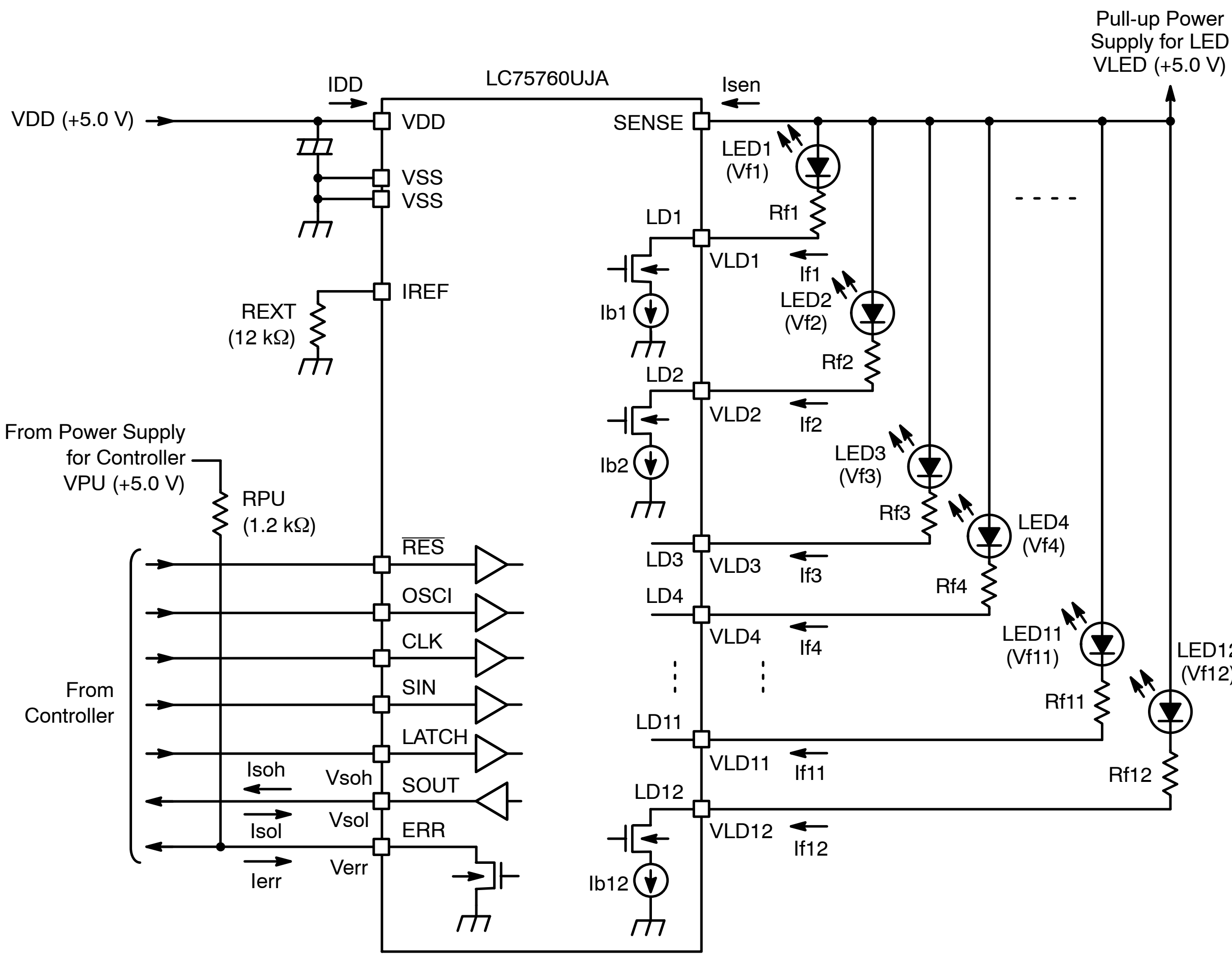
Total power dissipation Pd of LC75760UJA is the following.

Pd = 358 mW + 0.5 mW + 1.2 mW + 1.2 mW + 25 mW = 385.9 mW

The Pd is less than 430 mW of allowable power dissipation Pdmax, under T_A = 105°C operation on the glass-epoxy board of 76.2 mm × 114.3 mm × 1.6 mm with 2 layers. So the LSI can be operated under T_A = 105°C.

Application Sample 3

The following shows the calculation methods and note about the power dissipation when the drive like the open drain output drive is performed with connecting a current limiting resistor to the LED driver output. The power dissipation needs to be value less than allowable power dissipation Pdmax. In this application sample, LED driver output voltage might be lower level than 0.6 V of open detection voltage VLOP. So it might not be able to detect open abnormality of LED driver outputs. The open drain drive in this case is the method to drive LED with connecting current limiting resistance in order to stay current value less than constant current which is set by control data CAn7 to CAn0.



NOTE:	VLD1 to VLD12:	Output low-level voltage from LD1 pin to LD12 pin. (When Ifn < Ibn, n = 1 to 12. The values are around 0.5 V.)
	Vf1 to Vf12:	Forward voltage of LED connecting to LD12 pin from LD1 pin.
	If1 to If12:	Output current with PWM duty 100% from LD1 pin to LD12 pin. (LED forward current.)
	Ib1 to Ib12:	Constant Current from LD1 pin to LD12 pin set by control data CAn7 to Can0. (n = 1 to 12)
	Rf1 to Rf12:	Current limiting resistors connecting to LD12 pin from LD1 pin.
	Isen:	Input current of SENSE pin.
	VLED:	Pull-up voltage of LED driver output.
	Verr:	Output low-level voltage of ERR pin.
	Ierr:	Output low-level current of ERR pin.
	Vsoh:	Output high-level voltage of SOUT pin.
	Isoh:	Output high-level current of SOUT pin.
	Vsol:	Output low-level voltage of SOUT pin.
	Isol:	Output low-level current of SOUT pin.
	VDD:	Supply voltage.
	IDD:	Current drain.

Figure 3. Schematic of Application Sample 3

The Figure 3 is shown when LEDs are driven by the method like open drain output drive with current limiting resistance connecting to LED drivers. The power dissipation in this case can be generated by the following calculation.

1. Power dissipation Pd_LED of LED driver outputs from LD1 pin to LD12 pin.
   Pd_LED =
   VLD1 × If1 × PWM duty +
   VLD2 × If2 × PWM duty +
   VLD3 × If3 × PWM duty +
   VLD4 × If4 × PWM duty +
   VLD5 × If5 × PWM duty +
   VLD6 × If6 × PWM duty +
   VLD7 × If7 × PWM duty +
   VLD8 × If8 × PWM duty +
   VLD9 × If9 × PWM duty +
   VLD10 × If10 × PWM duty +
   VLD11 × If11 × PWM duty +
   VLD12 × If12 × PWM duty =
   (VLED − Vf1 − Rf1 × If1) × If1 × PWM duty +
   (VLED − Vf2 − Rf2 × If2) × If2 × PWM duty +
   (VLED − Vf3 − Rf3 × If3) × If3 × PWM duty +
   (VLED − Vf4 − Rf4 × If4) × If4 × PWM duty +
   (VLED − Vf5 − Rf5 × If5) × If5 × PWM duty +
   (VLED − Vf6 − Rf6 × If6) × If6 × PWM duty +
   (VLED − Vf7 − Rf7 × If7) × If7 × PWM duty +
   (VLED − Vf8 − Rf8 × If8) × If8 × PWM duty +
   (VLED − Vf9 − Rf9 × If9) × If9 × PWM duty +
   (VLED − Vf10 − Rf10 × If10) × If10 × PWM duty +
   (VLED − Vf11 − Rf11 × If11) × If11 × PWM duty +
   (VLED − Vf12 − Rf12 × If12) × If12 × PWM duty =
   0.5 V × If1 × PWM duty +
   0.5 V × If2 × PWM duty +
   0.5 V × If3 × PWM duty +
   0.5 V × If4 × PWM duty +
   0.5 V × If5 × PWM duty +
   0.5 V × If6 × PWM duty +
   0.5 V × If7 × PWM duty +
   0.5 V × If8 × PWM duty +
   0.5 V × If9 × PWM duty +
   0.5 V × If10 × PWM duty +
   0.5 V × If11 × PWM duty +
   0.5 V × If12 × PWM duty

2. Power dissipation Pd_SEN of SENSE pin.
   Pd_SEN = VLED × Isen

3. Power dissipation Pd_ERR of ERR pin.
   Pd_ERR = Verr × Ierr

4. Power dissipation Pd_SO of SOUT pin.
   Pd_SO = {(VDD − Vsoh) × Isoh + Vsol × Isol} / 2

5. Power dissipation Pd_VDD of VDD pin.
   Pd_VDD = VDD × IDD

Total power dissipation Pd of LC75760UJA has to be adjusted less than the allowable power dissipation Pdmax.

Pd = Pd_LED + Pd_SEN + Pd_ERR + Pd_SO + Pd_VDD < Pdmax

For example, in the case of electrical parameter such as the following condition, the power dissipation is the following.

1. Power dissipation Pd_LED of LED driver outputs from LD1 pin to LD12 pin.
   <Condition>
   VLED = 5.0 V, VLD1 to VLD12 = 0.5 V, Values setting constant current from LD1 pin to LD12 pin are 50 mA (= 1.2 V / 12 kΩ × 500 × 256 / 256), Vf1 to Vf4 = 2.0 V, Vf5 to Vf8 = 2.5 V, Vf9 to Vf12 = 3.0 V, Rf1 to Rf4 = 220 Ω, Rf5 to Rf8 = 150 Ω, Rf9 to Rf12 = 100 Ω, PWM duty values from LD1 pin to LD12 pin are 100%.

   Ifa = (VLED − Vfa − VLDa) / Rfa =
   5.0 V − 2.0 V − 0.5 V) / 220 Ω =
   11.4 mA (a = 1 to 4)
   Ifb = (VLED − Vfb − VLDb) / Rfb =
   (5.0 V − 2.5 V − 0.5 V) / 150 Ω =
   13.3 mA (b = 5 to 8)
   Ifc = (VLED − Vfc − VLDc) / Rfc =
   (5.0 V − 3.0 V − 0.5 V) / 100 Ω =
   15.0 mA (c = 9 to 12)

   Pd_LED =
   0.5 V × 11.4 mA × 100% + 0.5 V × 11.4 mA × 100% +
   0.5 V × 11.4 mA × 100% + 0.5 V × 11.4 mA × 100% +
   0.5 V × 13.3 mA × 100% + 0.5 V × 13.3 mA × 100% +
   0.5 V × 13.3 mA × 100% + 0.5 V × 13.3 mA × 100% +
   0.5 V × 15.0 mA × 100% + 0.5 V × 15.0 mA × 100% +
   0.5 V × 15.0 mA × 100% + 0.5 V × 15.0 mA × 100% =
   5.7 mW × 4 + 6.7 mW × 4 + 7.5 mW × 4 = 79.6 mW

2. Power dissipation Pd_SEN of SENSE pin.
   <Condition>
   VLED = 5.0 V, Isen = 0.1 mA (= IIH3)
   Pd_SEN = 5.0 V × 0.1 mA = 0.5 mW

3. Power dissipation Pd_ERR of ERR pin.
   <Condition>
   Verr = 0.3 V (= VOL1), Ierr = 4 mA
   Pd_ERR = 0.3 V × 4 mA = 1.2 mW

4. Power dissipation Pd_SO of SOUT pin.
   <Condition>
   Vsoh = VDD − 0.3 V (= VOH1), Isoh = 4 mA,
   Vsol = 0.3 V (= VOL1), Isol = 4 mA
   Pd_SO = [{VDD − (VDD − 0.3 V)} × 4 mA + 0.3 × 4 mA] / 2 = 1.2 mW

5. Power dissipation Pd_VDD of VDD pin.
   <Condition>
   VDD = 5.0 V, IDD = 5 mA (= IDD2)
   Pd_VDD = 5.0 V × 5 mA = 25 mW

Total power dissipation Pd of LC75760UJA is the following.

Pd = 79.6 mW + 0.5 mW + 1.2 mW + 1.2 mW + 25 mW = 107.5 mW

The Pd is less than 430 mW of allowable power dissipation Pdmax, under T_A = 105°C operation on the glass-epoxy board of 76.2 mm × 114.3 mm × 1.6 mm with 2 layers. So the LSI can be operated under T_A = 105°C.

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:
Literature Distribution Center for ON Semiconductor
19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA
Phone: 303−675−2175 or 800−344−3860 Toll Free USA/Canada
Fax: 303−675−2176 or 800−344−3867 Toll Free USA/Canada
Email: orderlit@onsemi.com

N. American Technical Support: 800−282−9855 Toll Free USA/Canada
Europe, Middle East and Africa Technical Support:
Phone: 421 33 790 2910

ON Semiconductor Website: **www.onsemi.com**

Order Literature: http://www.onsemi.com/orderlit

For additional information, please contact your local Sales Representative