

MBI6120 Application Note

Foreword

MBI6120 is a constant current LED driver for RGB cluster applications. The stability of data transmission has been improved through re-generation topology. This article mainly addresses five chapters

1. The module design, LED sorting and output current setting...etc.
2. The controller design, the notices including controller circuit, input signal... etc.
3. The production and setup, including the effect of hot swap, the design to reduce the surge voltage...etc.
4. The method of system testing.
5. Other applications notice, such as high V_{LED} application.

Chapter 1. Module Design

Figure 1 shows the MBI6120 application circuit.

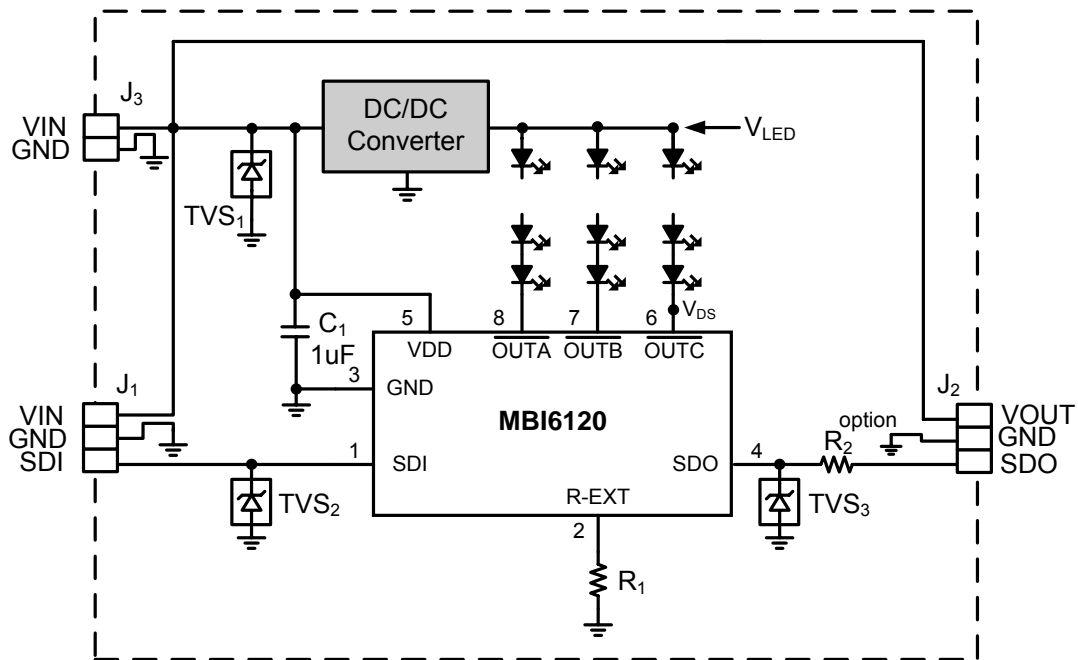


Figure 1. MBI6120 application circuit

1. Sorting the LED Forward Voltage

The higher V_{LED} may result in high voltage drop on MBI6120's output port while adopting LEDs with large variation in forward voltage and then cause overheat. Therefore, LED forward voltage (V_F) sorting is necessary.

2. Setting the Output Current

MBI6120 allows users to set the three LED current (I_{OUT}) by an external resistor, R_1 . After users decide the LED current, users can get a suitable R_1 by the following equation.

$$R_1 = (0.6V / I_{OUT}) \times 23 \dots \dots \dots (1)$$

R_1 must be placed close to MBI6120 in order to prevent R_1 from being disturbed. Moreover, the 1% tolerance resistor is recommended in order to obtain the accurate output current.

To keep the MBI6120 constant current, a sufficient voltage at \overline{OUTA} , \overline{OUTB} and \overline{OUTC} of MBI6120 (V_{DS}) is needed. Figure 2 shows the I-V curves of MBI6120. Users can refer to the figure and get a suitable V_{DS} . In general, the V_{DS} is slightly greater than the knee voltage. (Recommendation: $V_{DS} = V_{knee} + 0.2V$)

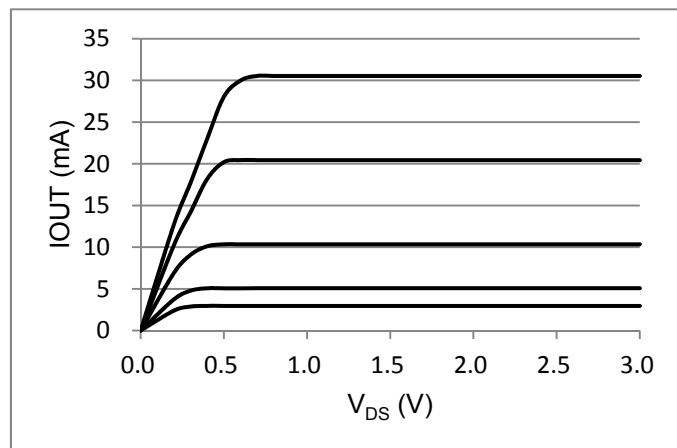


Figure 2. The relationship between I_{OUT} and V_{DS}

3. Setting LED Power

The minimum V_{LED} can be determined by the following equation

$$V_{LED, MIN.} = (V_{F, MAX.} \times n) + V_{DS} \dots \dots \dots (2)$$

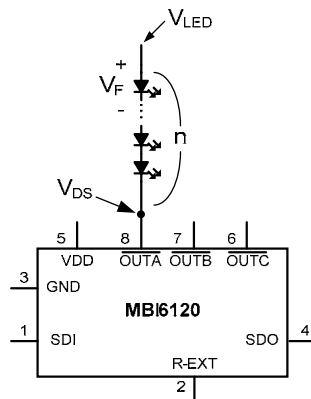


Figure 3. The sketch of minimum V_{LED} voltage

where $V_{F,MAX}$ represents the maximum forward voltage of LED, and n is the number of cascaded LEDs. The maximum sustaining voltage of $\overline{OUTA} \sim \overline{OUTC}$ is 17V. If the supply voltage of LED (V_{LED}) is over 17V, the IC will be damaged. For the higher V_{LED} application, please refer the P.13.

4. Power Distribution

Because of the impedance of power lines, the input voltage of each cluster might be different in the multi-cluster cascaded application, as figure 4 shows. Also, the V_{DD} voltage of MBI6027 might be interfered by the switching noise when V_{DD} and V_{LED} connect together, as figure 5 and 6 show. To prevent above problems, users can take the solutions, which are shown in figure 7 and 8. Figure 7 shows a DC/DC converter to isolate the V_{DD} and V_{LED} ; also the DC/DC converter can regulate the V_{LED} and provide enough voltage for LED used. Figure 8 shows the method for power distribution; it can reduce the voltage drop caused by power lines. For example, in the rule of UL1007, the maximum conductor impedance of AWG26 is 152Ω/km. It means that 1km power line is equal to 150Ω. If the used power line is 50cm and output current is 20mA, there will be 1.52mV voltage drop. If the voltage is lower than that of DC/DC converter supply voltage, users should use another power line with lower impedance.

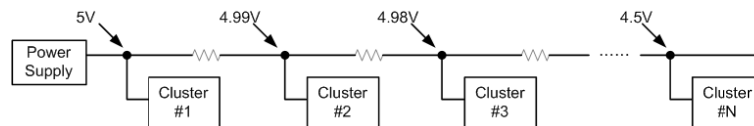


Figure 4. The sketch of dropout voltage in multi-cluster cascaded application

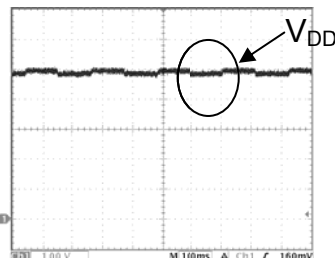


Figure 5. The poor waveform of V_{DD} - 1

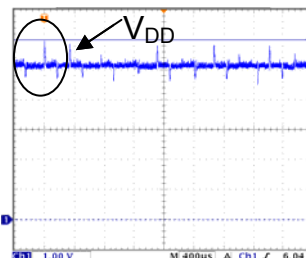


Figure 6. The poor waveform of V_{DD} - 2

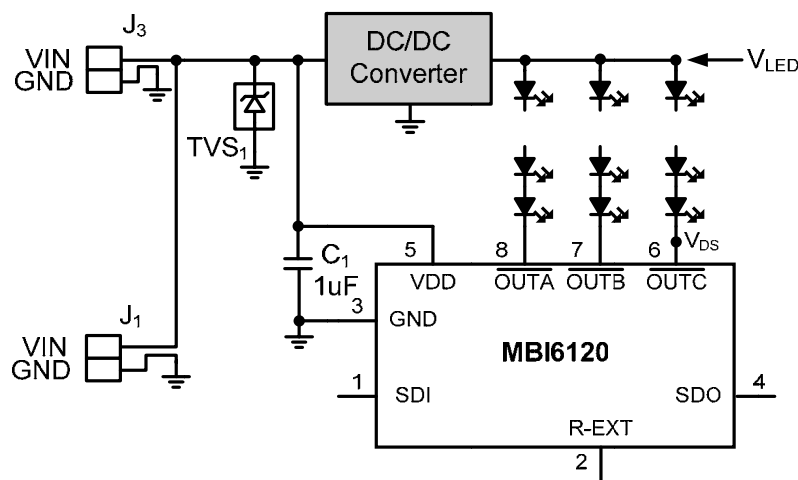
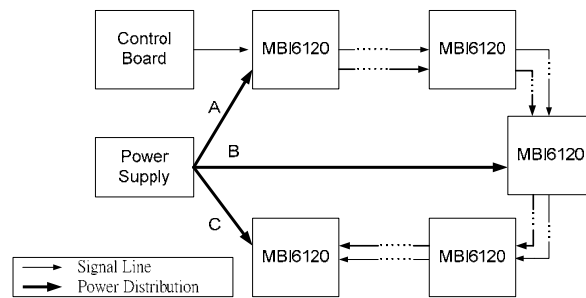


Figure 7. The proposed method of the input power

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Figure 8. The power distribution of clusters
Table 1. The specification of transmission line

UL 1007 CSA TR-64	Range		Conductor		Insulation		Tolerance mm	Maximum Conductor Resistance Ω/km	Permissible Current A	Minimum Insulation Resistance MΩ/km	(VAC/min) Insulation Potential Strength
	Temp °C	Voltage V	AWG	NO./MM	Thickness mm	O.D. mm					
Stranded	UL 80°C	300V	32	7/0.080	0.38	1.00	±0.10	703	1.6	15	2000
			30	7/0.100	0.38	1.10	±0.10	397	2.0		
			28	7/0.127	0.38	1.20	±0.10	248	2.5		
			26	7/0.160	0.38	1.30	±0.10	152	3.5		
			24	11/0.160	0.38	1.45	±0.10	88.6	5.0		
			22	17/0.160	0.38	1.60	±0.10	62.5	7.0		
			20	21/0.180	0.38	1.85	±0.10	39.5	9.0		
			18	34/0.180	0.38	2.10	±0.10	24.4	13.0		
Top-Coated(ATC)	CSA 90°C	300V	30	7/0.100	0.38	1.10	±0.10	397	2.0	15	2000
			28	7/0.127	0.38	1.20	±0.10	248.0	2.5		
			26	7/0.160	0.38	1.30	±0.10	152.0	4.0		
			24	7/0.200	0.38	1.45	±0.10	88.6	5.3		
Solid(TA)	CSA 90°C	300V	22	7/0.254	0.38	1.60	±0.10	62.5	7.2	15	2000
			26	1/0.404	0.38	1.25	±0.10	155	3.8		
			24	1/0.511	0.38	1.40	±0.10	92.4	5.3		
			22	1/0.643	0.38	1.55	±0.10	60.1	7.2		
	CSA 90°C	300V	20	1/0.813	0.38	1.70	±0.10	37.0	9.4	15	2000
			18	1/1.020	0.38	1.96	±0.10	23.6	13.0		

5. Signal Quality

MBI6120's SDI works with 3.3V and 5V signal levels. Figure 9 and figure 10 describe the signal waveforms with good quality.

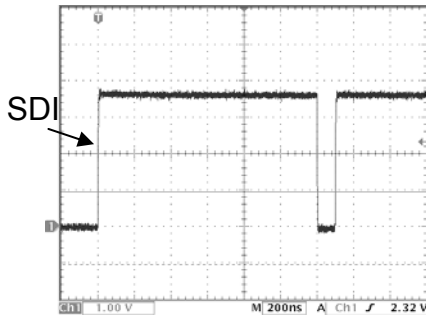


Figure 9. Good quality signal waveform(3.3V)

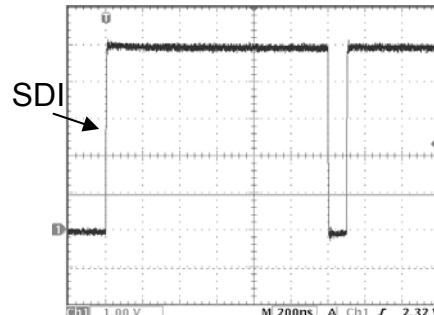


Figure 10. Good quality signal waveform(5V)

In order to reduce the noise interference, the cable wire with shielding is recommended to be the transmission line; also, the braid and drain wire of foil must be connected to ground.

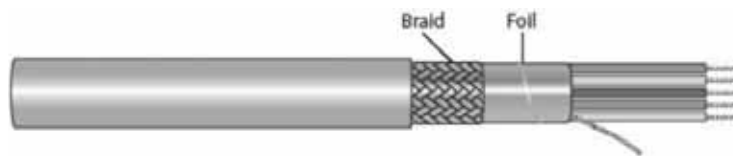


Figure 11. The cable wire with shielding

Chapter 2. Control Signal Design

1. Notice for Controller

To improve the validity of control signal, the control signal should be outputted after the powers of controller and module are stable and use the circuit of power on reset to initialize MBI6120. The controller's connector should add a GND to provide the common ground for controller and cluster.

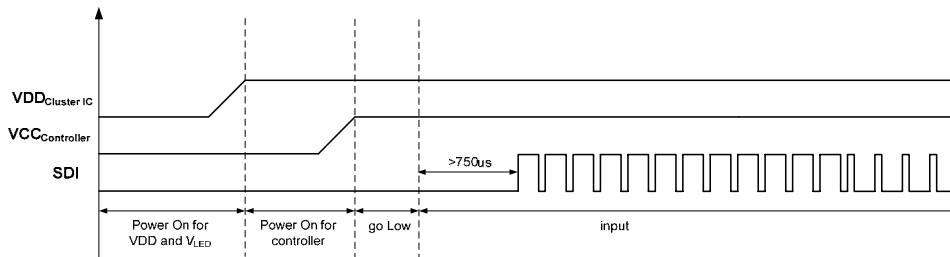


Figure 12. Power-on sequence

2. Wait time

Before the Header sends out, the SDI should be kept at low level to prevent the data transmission from being interfered. In order to realize the new gray scale and meet the image refresh time (T_{frame}), the duration of SDI low level should be calculated by the following equations

$$T_{wait} = T_{frame} - T_{data} \dots \dots \dots (3)$$

$$T_{wait} > 750\mu s \dots \dots \dots (4)$$

where T_{data} represents the time of transmission, T_{data} of 16-bits is $T_{data} = T_{bit} \times 36 \times (N+1) + T_{gap} \times (N+1)$, N is the amount of cascaded IC and T_{bit} is the 1-bit period of SDI.

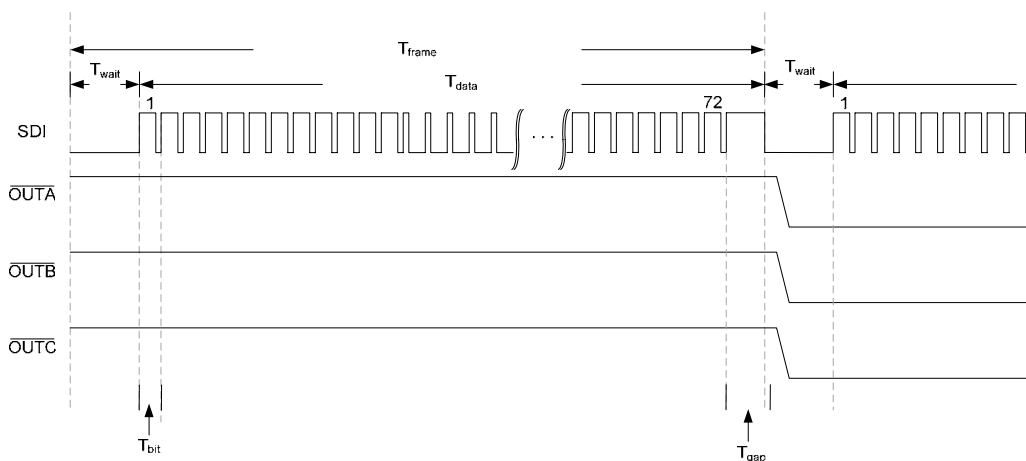


Figure 13. Diagram of prefix

Example

Number of MBI6120 in cascade: 64 pcs

Period of 1-bit SDI(T_{bit}): 1us (1/1MHz),

Refresh time of a frame: 16.67ms (1/60Hz).

From equation (3), $T_{wait} = 16.67ms - (1\mu s \times 36 \times (64+1) + 2\mu s \times (64+1)) = 14.2ms$. The time is larger than the time of 750us.

3. Input Signal

Please follow the datasheet to provide the correct Logic 1, Logic 0 and gap width. Each logic bit can't be interrupted and the variation of the bit width should be less than 10%. Controller only can read the memory data at gap, and the read time can't exceed 20us. The input signal should include the Header and Data.

3.1 Header

The correct Header must be transmitted before the gray scale data to make sure each MBI6120 can catch the gray scale data. The header includes H1, CLK, CMD, NUM.

Table 2. Header

Definition	Bit	Value	Function
H1	[35:24]	12'b111111111111	Data rate detection
CLK	[23:22]	xx (don't care)	Reserved
	[21:20]	2'b00 (default)	GCLK=5.2MHz (typ.)
		2'b01	GCLK=2.6MHz (typ.)
		2'b10	GCLK=1.3MHz (typ.)
CMD	[19:12]	2'b11	GCLK=650kHz (typ.)
		8'b00000000	Gray scale data
		8'b01010101	Software reset
		Other values	Ineffective, ignored
NUM	[11:10]	xx (don't care)	Reserved
	[9:0]	10'b0000000001~ 10'b1111111111	Number of cascading IC's

3.1.1 H1

H1 is used to detect the data rate, and it must be 12b'111111111111.

3.2.2 CLK

CLK is a GCLK frequency selector. The Header[23:22] is reserved bit, and is recommended to set 2'b00.

3.1.3 CMD

The MBI6120's CMD can be used to choose gray scale data or software reset. The software reset CMD will reset the IC and turned off the output ports.

3.1.4 NUM

The NUM will be minus one and passing, and the Most Significant Bit (MSB) will be exported first to the next IC. When the data of NUM is zero, the data will be latched to register. For example, if there are two MBI6120 in cascaded, the NUM will be 2(10'b0000000010).

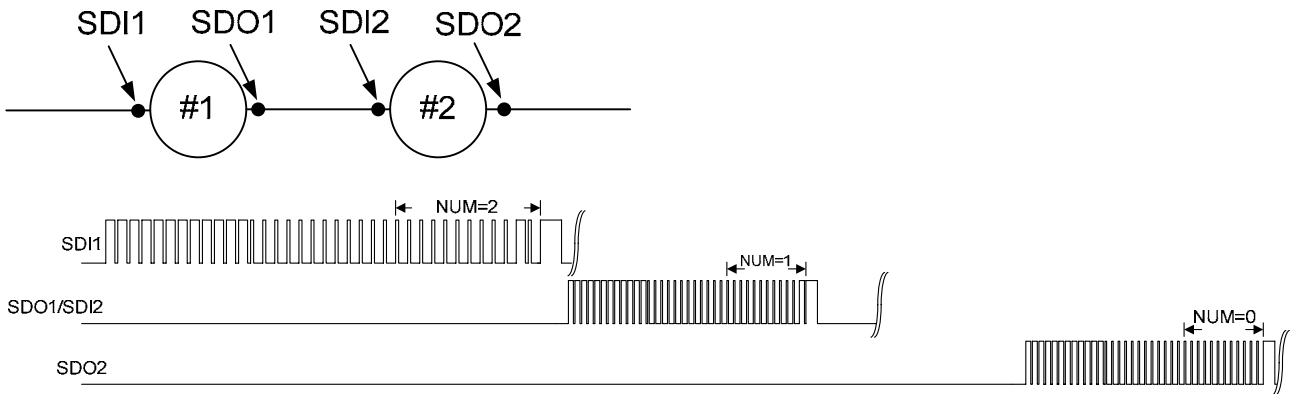


Figure 14. Diagram of NUM

3.2 Gap

Between each data, a gap is needed to recognize the data length. Once the data length isn't 36-bit, MBI6120 will ignore the present data until next Header comes. The Read/Write command should be executed in the duration of gap, and the processing time can't exceed 20us.

3.3 Data

The data should come out from MSB in /OUTA of the last driver. After the software reset command, setting all the bits to 0 is recommended.

Following shows the example of two MBI6120 in cascade with different commands.

Gray Scale Data

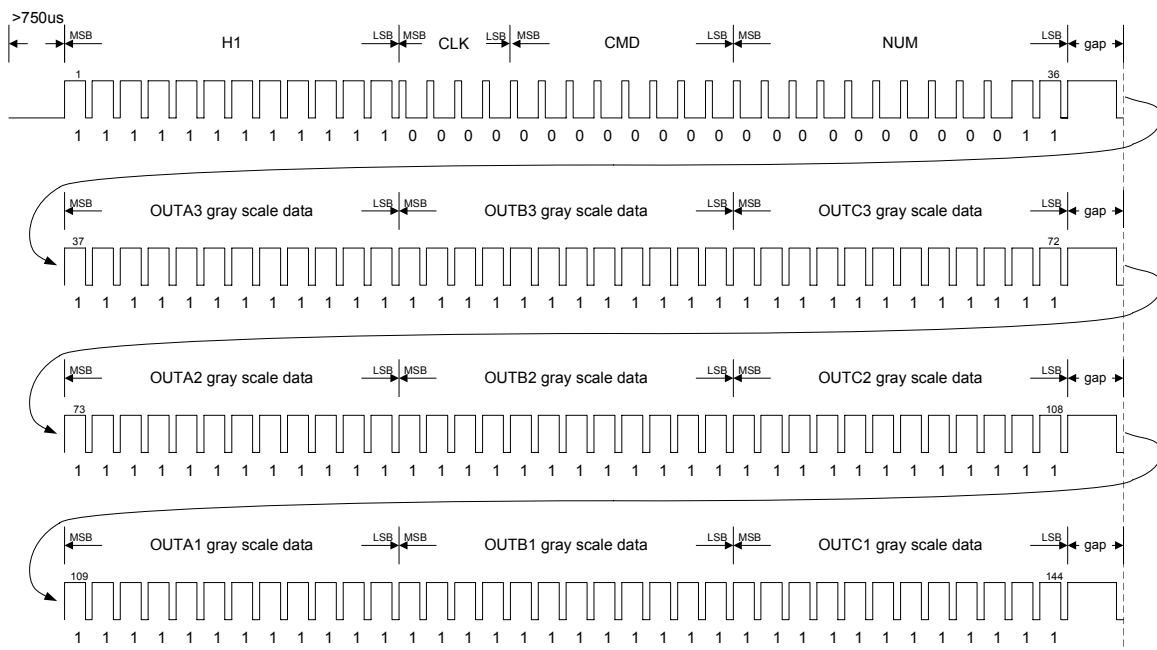


Figure 15. The example of gray scale data

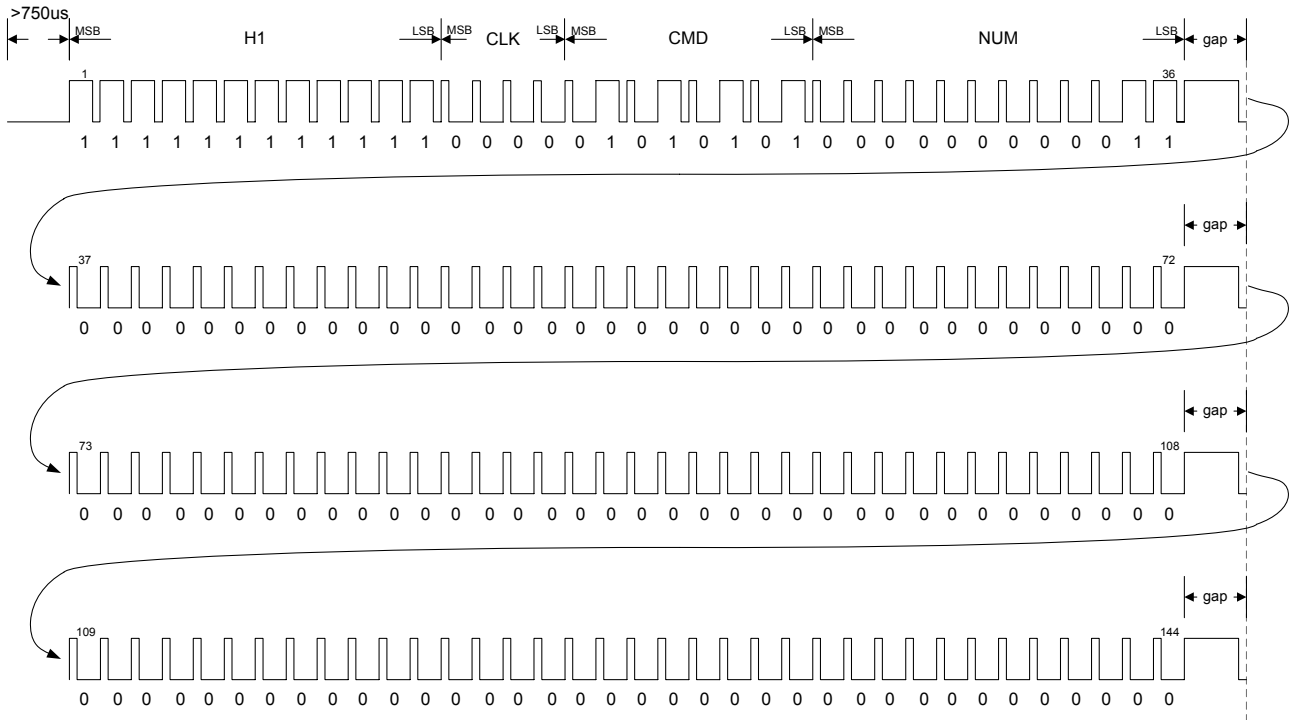
Software Reset


Figure 16. The example of software reset

Chapter 3. Production and Setup

1. The Effect of Hot Swap

Hot swapping means the action of connecting or disconnecting the pin of VDD/SDI/SDO of MBI6120. It will induce the heavy instantaneous current and high voltage, and then damage the IC. Besides increasing the EOS protection component as mentioned, users also may add the longer ground terminal in connectors, and operate the correct procedures to avoid hot swap.

2. Design to Reduce Strike Voltage

2.1 Cascaded Resistance

Adding a resistor at SDO can reduce the probability of IC been damaged by hot swap. The larger resistance results the lower probability of damage problem, and the lower speed of transmission. The recommended resistance of R_2 , which is shown in figure 17, is 10Ω .

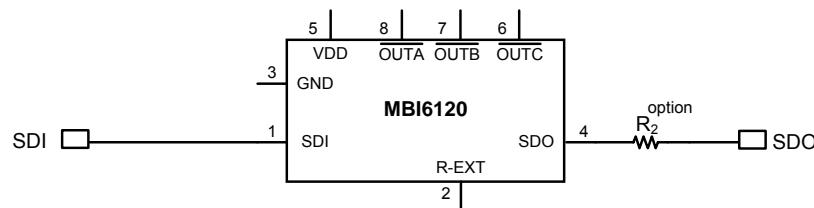


Figure 17. The schematic of cascaded resistance

2.2 Connector

When setting up or removing the connector of cluster instantly, in order to reduce the unexpected spike voltage and to avoid IC been burned out, users need to turn off the power, and then set up or remove the cluster. It is better to connect GND first. Users can design the longer GND terminal in connector pin than in VDD terminal in connector to reduce the unexpected strike voltage, as shown in figure 18.

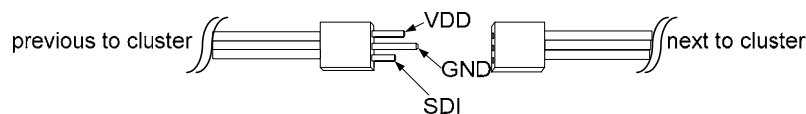


Figure 18. The safety design of longer terminal ground

2.3 Transient Voltage Suppressor

All Macroblock products have passed the standard of ESD protection. But to enhance the capacity of Electrical Over Stress (EOS) protection, an external device, Transient Voltage Suppressor (TVS), is necessary. Figure 19 shows the positions of TVS₁~TVS₃, and followings are the guidelines for TVS selection.

Select TVS₁

- The maximum Reverse Stand-Off Voltage (V_{RWM}) should be equal to 12V.
- Users should check the peak pulse current rating (IPP) and clamping voltage (V_c) to select the Peak Pulse Power Dissipation (P_{PPM}).
- TVS diode should be placed to the pins that need to protect as close as possible to prevent the EOS.

Select TVS₂ and TVS₃

- The maximum Reverse Stand-Off Voltage (V_{RWM}) should be equal to 5V.
- Users should check the peak pulse current rating (IPP) and clamping voltage (V_c) to select the Peak Pulse Power Dissipation (P_{PPM}).
- TVS diode should be placed to the protected pins as close as possible to prevent the EOS.

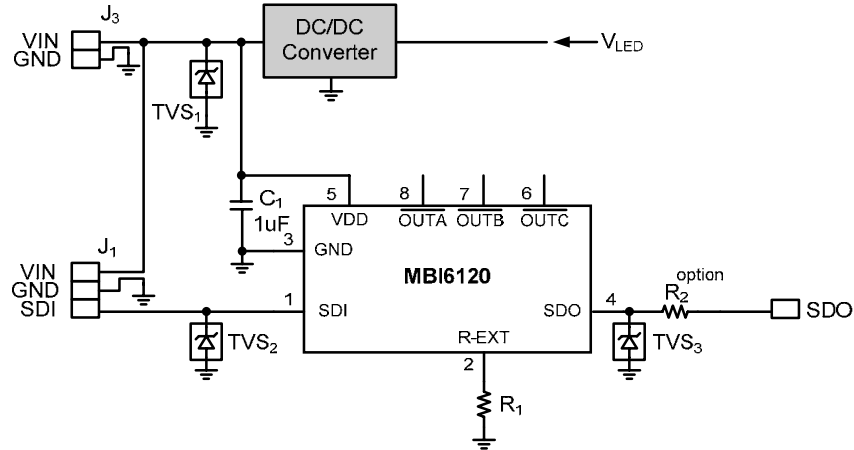


Figure 19. Apply the electrical overstress protection

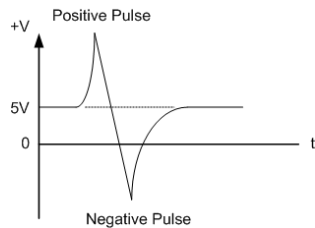


Figure 20. Without use EOS component

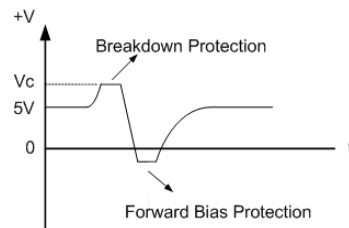


Figure 21. With use EOS component

3. Production and Setup procedures

The following procedures should be observed in producing and installing the modules. In order to avoid the controller from providing a valid power to the IC and causing the EOS through the ESD protection circuit.

Modules in the production and installation should carefully follow the correct procedures:

- Step 1: Before install the module, please turn all the power off.
- Step 2: The procedure of electrostatic discharge should be taken before connecting the cluster.
- Step 3: Make sure the grounding system has been properly grounded.
- Step 4: Make sure all the conducting wires of power supply and controller have completed and correctly contacted with connector.
- Step 5: After the above procedures have been executed, then start the system power supply.
- Step 6: After the system power is stable, then start the controller power supply.
- Step 7: Before the procedures of cluster removing or repairing welding, users have to turn off the controller power first and then the system power. After the residual charge has been completely discharged, then the rework procedures can be executed.

4. Printed Circuit Board Notice

1. Users should avoid empty solder, cold solder, and split solder in manufacturing process of printed circuit board (PCB).
2. Device layout should avoid approaching the board edge of PCB.
3. To design the longer size of PCB, it is suggested to select the thick slab value of PCB to avoid soldering issues due to board bending.

Chapter 4. The Method of System Testing

Since the pulse width of SDI is related to the signal quality and series count, after the whole system has finished the assembly, please use the SDI with 10us pulse width pre bit to verify the system stability. The gray scales of RGB are 12'b010101010101, and then the turn on sequence of RGB LEDs will be R→G→B→R→G→ . If the system works normal, please reduce the SDI pulse width 0.1us pre step, until system works abnormal. If SDI with 10us pulse width still can't work, please check the pulse width of logic0/1.

Chapter 5. Other application Notice

1. Higher V_{LED} Application

In more cascaded LEDs strings application, if the V_{LED} is larger than the sustaining voltage of $\overline{OUTA} \sim \overline{OUTC}$, MBI6120 might be damaged when the IC is turned off. The simplest method is to parallel a resistor ($R_3 \sim R_5$) at the output terminals of MBI6120, as shown in figure 22. When the IC is turned off, the LED will generate a small current from the paralleled resistor, and then the V_{DS} will not exceed the sustaining voltage of output terminal.

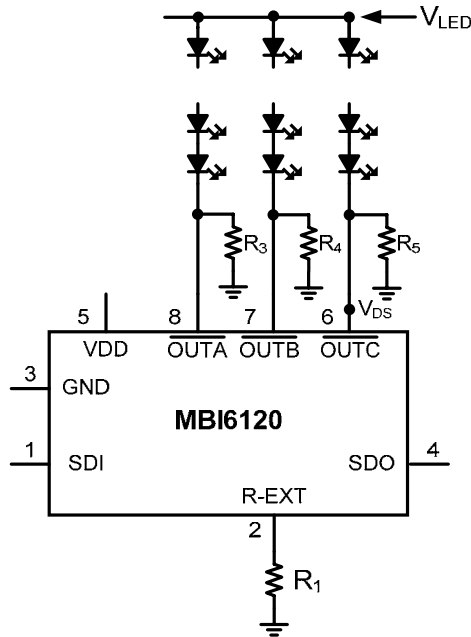


Figure 22. The application circuit of high V_{LED}

Users can follow the steps below to calculate the paralleled resistor.

1. Find out the LED current ($I_{LED-CUT}$), which results in the invisible LED brightness.
2. Calculate the resistor

$$R_3 \sim R_5 = (V_{LED} - N \times V_{F, LED-CUT (MAX)}) / I_{LED-CUT} \dots\dots\dots (5)$$

where N is the cascaded LED number, and $V_{F, LED-CUT (MAX)}$ is the LED forward voltage under $I_{LED-CUT}$. The calculation of $V_{LED} - N \times V_{F, LED-CUT (MAX)}$ must be smaller than the sustaining voltage of MBI6120's output terminal.

3. Parallel the $R_3 \sim R_5$ to the output terminal and turn off MBI6120. Make sure the LED brightness is invisible and V_{DS} is smaller than 17V.

Example: The V_{LED} is 24V, and the cascaded LED number is 11. Please calculate the paralleled resistor to prevent the IC from being damaged.

Table 3. The example of LED I-V data

	Invisible lighting range						Visible lighting range							
$V_f(V)$	1.40	1.42	1.43	1.44	1.45	1.48	1.50	1.60	1.80	2.00	2.10	2.11	2.20	2.25
$I_f(mA)$	0.0003	0.0005	0.0007	0.0009	0.0011	0.0024	0.0038	0.046	2.705	12.8	19.46	20.2	26.75	30.64

 1. Find out the $I_{LED-CUT}$

Table 3 is the I-V data of the LED in this example, and the $I_{LED-CUT}$ on this table is 0.0024mA.

 2. From equation (5), the $R_3 \sim R_5$ are $(24V - 11 \times 1.48V) / 0.0024mA = 3.2M\Omega$. In this example, select a $3.3M\Omega$ resistor with 0603 package to be $R_3 \sim R_5$. And when IC turns off the V_{DS} should be $24V - 11 \times 1.48V = 7.72V$. It is smaller than 17V.

When $R_3 \sim R_5$ are connected to the output terminals, and MBI6120 are turned off, the measured V_{DS} is 7.61V, and the LED current is 0.0023mA. So that the LED brightness is invisible.

2. Logic Level Issue

If users have to use the long power line on the PCB, the distributed capacitors, which figure 23 shows, are recommended. The value of C_d depends on the distance between each power line.

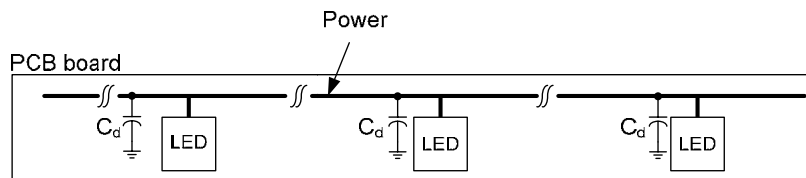


Figure 23. The sketch of distributed capacitance

Summary

In the application of multiple clusters cascaded, the following notices must be taken

1. The transmission line with small parasitic inductance is required to enhance the signal quality.
2. To prevent the insufficient V_{LED} , which is caused by the conductor resistance in transmission line, results the problem of cluster brightness unbalance, please refer figure 7 to design the power source.
3. Please refer to chapter 3, "Production and Installation", to protect IC being damaged from hot-plug in.

Please take a note, even the processes in chapter 3 have been executed, it only can reduce the probability of burn-out when hot-plug in, can't totally solve the problem.