Charge Pump for White LED

RN5T655

Development Specifications

Rev.1.1

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RICOH COMPANY, LTD.
Electronic Devices Company
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1. **Outline**

RN5T655 contains a constant frequency charge pump to optimize for white LED application. It drives up to 6 LEDs with constant current for LED brightness matching. LED enabling/disabling and current are controllable through single wire serial pulse I/F.

2. **Feature**

- **White LED Charge Pump**
  - Current capability: Total currents capability 120mA
  - Up to 20mA/LED drivable for 2 Sub LEDs
  - Up to 20mA/LED for 4 Main LEDs.
  - 1x/1.5x/2x charge pump mode

- **Flexible Brightness Control**
  - Main LED and sub LEDs individually controllable.
  - ON/OFF control
  - 4 main LED and 2 sub LED drivable
  - Fully programmable current with Single Wire serial pulse I/F: 16-step logarithmic scale

- **Others**
  - Soft-start circuit
  - Short-circuit protection, Open-circuit and Thermal Protection
  - Thermal Shutdown Function

- **Package**
  - 16pin QFN package (Body size: 3 x 3, Pin pitch 0.4mm)

- **Process**
  - CMOS process
3. Pin Configuration

Fig 3-1 Pin Configuration
4. Typical Application Circuit

![Typical Application Circuit Diagram](image)

Fig 4-1 Typical Application Circuit
## 5. Pin Description

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>I/O</th>
<th>Function</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C1P</td>
<td>I/O</td>
<td>Charge pump boost capacitor connection. Connect 1 μF capacitor between C1P and C1M.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>C2P</td>
<td>I/O</td>
<td>Charge pump boost capacitor connection C2P and C2M.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>C2M</td>
<td>I/O</td>
<td>Charge pump boost capacitor connection</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>GND1</td>
<td>I/O</td>
<td>Ground1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>C1M</td>
<td>I/O</td>
<td>Charge pump boost capacitor connection</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>VDD</td>
<td>I/O</td>
<td>Power supply for charge pump</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>DIN6</td>
<td>O</td>
<td>LED driver current control output 6</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>DIN5</td>
<td>O</td>
<td>LED driver current control output 5</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>DIN4</td>
<td>O</td>
<td>LED driver current control output 4</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>DIN3</td>
<td>O</td>
<td>LED driver current control output 3</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>DIN2</td>
<td>O</td>
<td>LED driver current control output 2</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>DIN1</td>
<td>O</td>
<td>LED driver current control output 1</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>GND2</td>
<td>I/O</td>
<td>Ground2</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>DIMS</td>
<td>I/O</td>
<td>Input of control signal for Sub LED</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>DIMM</td>
<td>I/O</td>
<td>Input of control signal for Main LED</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>VOUT</td>
<td>O</td>
<td>LED driver voltage output</td>
<td></td>
</tr>
</tbody>
</table>

Table 5-1
6. Functional Description

RN5T655 charge pump drives 6 LEDs with regulated constant current for uniform intensity. DIMM/DIMS input pin is used to enable, disable and adjust current for each with a 16-logarithmic scale.

<table>
<thead>
<tr>
<th>Luminance</th>
<th>Count value</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFF⇒ON(100%)</td>
<td>0</td>
</tr>
<tr>
<td>88.0%</td>
<td>1</td>
</tr>
<tr>
<td>75.8%</td>
<td>2</td>
</tr>
<tr>
<td>63.5%</td>
<td>3</td>
</tr>
<tr>
<td>51.1%</td>
<td>4</td>
</tr>
<tr>
<td>44.8%</td>
<td>5</td>
</tr>
<tr>
<td>38.5%</td>
<td>6</td>
</tr>
<tr>
<td>32.0%</td>
<td>7</td>
</tr>
<tr>
<td>25.5%</td>
<td>8</td>
</tr>
<tr>
<td>22.2%</td>
<td>9</td>
</tr>
<tr>
<td>18.8%</td>
<td>10</td>
</tr>
<tr>
<td>15.4%</td>
<td>11</td>
</tr>
<tr>
<td>11.9%</td>
<td>12</td>
</tr>
<tr>
<td>8.3%</td>
<td>13</td>
</tr>
<tr>
<td>4.5%</td>
<td>14</td>
</tr>
<tr>
<td>0.0%</td>
<td>15</td>
</tr>
</tbody>
</table>
6.1 **PWM Adjustment with Time Control**

When DIMM/DIMS goes high, LEDs are enabled at full brightness. After subsequent low going pulse reduces LED current in logarithmical scale.

### 6.1.1 Disable LED

LED can be powered off by driving DIMM/DIMS pin low longer than $t_{OFF}$.

```
DIMM or DIMS
Soft-start
100% 88.0% 75.8% 63.5%

IMLED or ISLED
```

### 6.1.2 Initialization of LED

Brightness can be adjusted to initial value by driving DIMM/DIMS pin high longer than $t_{RESET}$.

(LED remains power-on.)

```
DIMM or DIMS
Soft-start
100% 88.0% 75.8% 63.5%

IMLED or ISLED
```

* Timer description

- $t_{RESET}$ timer starts at rising edge of the input clock from DIMM/DIMS and is cleared at rising edge of input clock from DIMM/DIMS.
- $t_{OFF}$ timer starts at falling edge of the input clock from DIMM/DIMS and turns off when timer overflows.
6.2 Operation Flow

Case 1:

1. Power ON

   Power ON : DIMM/DIMS pin turns to "H"

2. Luminance Setting

   Luminance Setting Value: 5.1% (4 Pulses)

3. Wait Subroutine (RESET)

   DIMM/DIMS pin is maintained at "H" during tRESET.

4. Luminance Setting

   Dimmer Setting Value: 22.2% (9 Pulses)

   IRQ is generated

5. Wait Subroutine (RESET)

6. Luminance Setting

Wait Subroutine: The subroutine needs to be inserted to any status.
Case2:

1. Power ON
   - Power ON: DIMM/DIMS pin turn to "H"
   - Luminance Setting Value: 51.1% (4 Pulses)

2. Luminance Setting

3. Wait Subroutine (tRESET)
   - DIMM/DIMS pin is maintained at "H" during tRESET.

4. Luminance Setting
   - Dimmer Setting Value: 22.2% (9 Pulses)

5. Wait Subroutine (tOFF)
   - DIMM/DIMS pin is maintained at "L" during tOFF.

6. Power OFF
   - IRQ is generated

7. Power ON

8. Luminance Setting
   - Power ON: DIMM/DIMS pin turns to "H"
   - Luminance Setting Value: 51.1% (4 Pulses)

Note*: Power ON/OFF means RN5T655 ON/OFF, not the system's.
Case X

1. Power ON

2. Luminance Setting

3. Wait Subroutine (RESET)

4. Luminance Setting

Power ON: DIMM/DIMS pin turns to "H"

Luminance Setting Value: 51.1% (4 Pulses)

IRQ is generated

DIMM/DIMS pin is maintained at "H" during tRESET.

Luminance Setting Value: 51.1% (4 Pulses)

IRQ is generated

3. Wait Subroutine (RESET)

1. Power ON 2. Luminance Setting 4. Luminance Setting

DIMM or DIMS

Softstart 100%

88.0%

77.0%

65.3%

51.1%

88.0%

77.0%

65.3%

51.1%

DMLED or ISLED
## 7. Electrical Characteristics

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Condition</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Charge Pump</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_{IN} )</td>
<td>Operating Voltage</td>
<td>VDD voltage</td>
<td>2.7</td>
<td>4.5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>( I_{OUT} )</td>
<td>Max. Output current</td>
<td>VDD&gt;3.2V, VOUT voltage*1</td>
<td>120</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( R_{ON} )</td>
<td>Output resistance*2</td>
<td>1x mode, (VDD-Vout)/Iout</td>
<td>1.2</td>
<td>5.0</td>
<td>10.5</td>
<td>Ω</td>
</tr>
<tr>
<td>( V_{OVP} )</td>
<td>Over voltage protection</td>
<td>VOUT Rising</td>
<td>5.2</td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( F_{OSC} )</td>
<td>Switching Frequency</td>
<td>-</td>
<td>1.25</td>
<td>MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( T_{SOFT} )</td>
<td>Soft-start time</td>
<td>-</td>
<td>200</td>
<td>μs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I_{sc} )</td>
<td>Supply current</td>
<td>1x mode</td>
<td>1</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I_{ss} )</td>
<td>Standby supply current</td>
<td>VDD current</td>
<td>5</td>
<td>μA</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LED Driver</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I_{sink} )</td>
<td>Maximum Sink Current</td>
<td>Each DIN1~6</td>
<td>20</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( A_{CC} )</td>
<td>LED current accuracy (Main)</td>
<td>Setting DATA0, DIN_ =0.25V*3</td>
<td>-5</td>
<td>5</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LED current accuracy (Sub)</td>
<td>Setting DATA0, DIN_ =0.25V*3</td>
<td>-5</td>
<td>5</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Mat</td>
<td>LED current matching</td>
<td>Main. Vfdiff=0.4V*4</td>
<td>-2</td>
<td>2</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>( V_{DROP} )</td>
<td>Current Regulator Dropout</td>
<td>Setting DATA0,Isink=20mA*5</td>
<td>250</td>
<td>mV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I_{LEAK} )</td>
<td>DIN1-6 leakage in shutdown</td>
<td>-</td>
<td>0.01</td>
<td>μA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I_{RESET} )</td>
<td>Reset time</td>
<td>-</td>
<td>20</td>
<td>ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I_{OFF} )</td>
<td>Off time</td>
<td>-</td>
<td>20</td>
<td>ms</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note*1: VOUT is decided according to charge pump operation mode, as shown below
\[
V_{OUT} = x \times VDD - R_{ON} \times I_{OUT} \quad (x \text{ means 1, 1.5 or 2})
\]

Note*2: The relationship of output resistance \( R_{ON} \) is shown below.
\[
R_{ON} = 2R_{switch} + 4ESRC_{1,2} + ESR_{Cout} + 1/f_{osc} \times C_{1,2}
\]

Note*3: LED current accuracy depends on applied DIN_ voltage when current measured. The most accurate value can be measured when DIN_ voltage is equal to regulator dropout voltage. Dropout voltage changes by setting DATA.

Note*4: Matching is defined \( (I_{ave_\_} - I_{led_\_}) / I_{ave_\_} \). Iave_\_ means average current Main. Maximum forward voltage difference is estimated within 0.4V.
For Main, Iave_main = (Iled1 + Iled2 + Iled3 + Iled4) / 4

Note*5: The regulation voltage of DIN_ is related to LED current. The smaller the set current becomes, the smaller the regulated voltage becomes.
8. **Absolute Maximum Ratings**

Exposure to the condition exceeded Absolute Maximum Ratings may cause the permanent damages and affects the reliability and safety of both device and systems using the device. The functional operations cannot be guaranteed beyond specified values in the recommended conditions.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Condition</th>
<th>Rated value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDD</td>
<td>Power Supply Voltage</td>
<td>Battery Voltage Input Pins</td>
<td>-0.3~6.0</td>
<td>V</td>
</tr>
<tr>
<td>VIN</td>
<td>Input Voltage Range</td>
<td>All Input Pins</td>
<td>-0.3~VDD+0.3</td>
<td>V</td>
</tr>
<tr>
<td>PD</td>
<td>Package Allowable Dissipation</td>
<td>Mounted on Board, $T_a=70^\circ$C</td>
<td>250</td>
<td>mW</td>
</tr>
<tr>
<td>$T_{stg}$</td>
<td>Storage Temperature</td>
<td>-</td>
<td>-55~+125</td>
<td>$^\circ$C</td>
</tr>
</tbody>
</table>

Note*: Duration = 200ms
9. Package Information

UNIT: mm