Features
- Full-wave Current Sensing
- Mains Supply Variation Compensated
- Programmable Load-current Limitation with Over- and High-load Output
- Variable Soft Start
- Voltage and Current Synchronization
- Automatic Retriggering Switchable
- Triggering Pulse Typically 125 mA
- Internal Supply-voltage Monitoring
- Current Requirement ≤ 3 mA
- Temperature-compensated Reference Voltage

Applications
- Advanced Motor Control
- Grinder
- Drilling Machine

Description
The U2010B is designed as a phase-control circuit in bipolar technology for motor control applications with load-current feedback and overload protection. It enables load-current detection and has a soft-start function as well as reference voltage output.

Figure 1. Block Diagram
General Description

Mains Supply

The U2010B contains voltage limiting and can be connected with the mains supply via D1 and R1. Supply voltage – between pin 10 and pin 11 – is smoothed by C1.

In the case of $V_6 \leq 70\%$ of the overload threshold voltage, pins 11 and 12 are connected internally whereby $V_{\text{sat}} \leq 1.2\, \text{V}$. When $|V_6| \geq |V_{70}|$, the supply current flows across D3.
Pin Configuration

Figure 3. Pinning DIP16/SO16

Pin Description

<table>
<thead>
<tr>
<th>Pin</th>
<th>Symbol</th>
<th>Function</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>ISENSE</td>
<td>Load current sensing</td>
</tr>
<tr>
<td>2</td>
<td>ISENSE</td>
<td>Load current sensing</td>
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<tr>
<td>3</td>
<td>Cϕ</td>
<td>Ramp voltage</td>
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<tr>
<td>4</td>
<td>CONTROL</td>
<td>Control input</td>
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<td>5</td>
<td>COMP</td>
<td>Compensation output</td>
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<td>6</td>
<td>ILOAD</td>
<td>Load current limitation</td>
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<tr>
<td>7</td>
<td>CSOFT</td>
<td>Soft start</td>
</tr>
<tr>
<td>8</td>
<td>VREF</td>
<td>Reference voltage</td>
</tr>
<tr>
<td>9</td>
<td>MODE</td>
<td>Mode selection</td>
</tr>
<tr>
<td>10</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>11</td>
<td>VS</td>
<td>Supply voltage</td>
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<tr>
<td>12</td>
<td>HIGH LOAD</td>
<td>High load indication</td>
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<td>13</td>
<td>OVERLOAD</td>
<td>Overload indication</td>
</tr>
<tr>
<td>14</td>
<td>VRϕ</td>
<td>Ramp current adjust</td>
</tr>
<tr>
<td>15</td>
<td>VSYNC</td>
<td>Voltage synchronization</td>
</tr>
<tr>
<td>16</td>
<td>OUTPUT</td>
<td>Trigger output</td>
</tr>
</tbody>
</table>
The series resistance $R_1$ can be calculated as follows:

$$R_{1\text{max}} = \frac{V_{\text{mains}} - V_{S\text{max}}}{2 \times I_{\text{tot}}}$$

where:

- $V_{\text{mains}}$ = Mains supply voltage
- $V_{S\text{max}}$ = Maximum supply voltage
- $I_{\text{tot}}$ = Total current consumption = $I_{S\text{max}} + I_x$
- $I_{S\text{max}}$ = Maximum current consumption of the IC
- $I_x$ = Current consumption of the external components

Voltage Monitoring

When the voltage is built up, uncontrolled output pulses are avoided by internal voltage monitoring. Apart from that, all latches in the circuit (phase control, load limit regulation) are reset and the soft-start capacitor is short-circuited. This guarantees a specified start-up behavior each time the supply voltage is switched on or after short interruptions of the mains supply. Soft start is initiated after the supply voltage has been built up. This behavior guarantees a gentle start-up for the motor and automatically ensures the optimum run-up time.

Phase Control

The function of the phase control is mainly identical to the well-known IC U211B. The phase angle of the trigger pulse is derived by comparing the ramp voltage $V_3$, which is mains-synchronized by the voltage detector, with the set value on the control input, pin 4. The slope of the ramp is determined by $C\phi$ and its charging current $I_\phi$. The charging current can be varied using $R_\phi$ at pin 14. The maximum phase angle, $\alpha_{\text{max}}$, can also be adjusted by using $R_\phi$ (minimum current flow angle $\phi_{\text{min}}$), see Figure 5 on page 10.

When the potential on pin 3 reaches the set point level of pin 4, a trigger pulse width, $t_p$, is determined from the value of $C\phi$ ($t_p = 9 \mu$s/nF). At the same time, a latch is set with the output pulse as long as the automatic retriggering has not been activated. When this happens, no more pulses can be generated in that half cycle. The control input at pin 4 (with respect to pin 10) has an active range from $V_8$ to -1 V. When $V_4 = V_8$, then the phase angle is at its maximum, $\alpha_{\text{max}}$, i.e., the current flow angle is minimum. The minimum phase angle, $\alpha_{\text{min}}$, is set with $V_4 \geq -1$ V.

Automatic Retriggering

The current-detector circuit monitors the state of the triac after triggering by measuring the voltage drop at the triac gate. A current flow through the triac is recognized when the voltage drop exceeds a threshold level of typically 40 mV.

If the triac is quenched within the relevant half-wave after triggering (for example owing to low load currents before or after the zero crossing of the current wave, or for commutator motors, owing to brush lifters), the automatic retriggering circuit ensures immediate retriggering, if necessary with a high repetition rate, $t_{pp}/t_p$, until the triac remains reliably triggered.
Current Synchronization
Current synchronization fulfills two functions:

– Monitoring the current flow after triggering.
  In case the triac extinguishes again or does not switch on, automatic triggering is activated until the triggering is successful.

– Avoiding triggering due to an inductive load.
  In the case of inductive load operation, the current synchronization ensures that in the new half wave, no pulse will be enabled as long as there is a current available from the previous half wave, which flows from the opposite polarity to the actual supply voltage.

The current synchronization as described above is a special feature of the U2010B. The device evaluates the voltage at the pulse output between gate and reference electrode of the triac. As a result, no separate current synchronization input with specified series resistance is necessary.

Voltage Synchronization with Mains Voltage Compensation
The voltage detector synchronizes the reference ramp with the mains supply voltage. At the same time, the mains-dependent input current at pin 15 is shaped and rectified internally. This current activates the automatic retriggering and at the same time is available at pin 5. By suitable dimensioning, it is possible to obtain the specified compensation effect. Automatic retriggering and mains voltage compensation are not activated until \(|V_{15-10}| \) increases to 8 V. The resistance \( R_{sync} \) defines the width of the zero voltage cross over pulse, synchronization current, and hence the mains supply voltage compensation current.

Figure 4. Suppression of Mains Voltage Compensation and Retrigger Automatic

If the mains voltage compensation and the automatic retriggering are not required, both functions can be suppressed by limiting \(|V_{15-10}| \leq 7 \) V, see Figure 4.

Load-current Compensation
The circuit continuously measures the load current as a voltage drop at resistance \( R_6 \). The evaluation and use of both half waves results in a quick reaction to load-current change. Due to the voltage at resistance \( R_6 \), there is a difference between both input currents at pins 1 and 2. This difference controls the internal current source, whose positive current values are available at pins 5 and 6. The output current generated at pin 5 contains the difference from the load-current detection and from the mains voltage compensation, see Figure 2 on page 2.
The efficient impedance of the set-point network generates a voltage at pin 4. A current, flowing out of pin 5 through $R_{10}$, modulates this voltage. An increase of mains voltage causes the increase of control angle $\alpha$, an increase of load current results in a decrease in the control angle. This avoids a decrease in revolution by increasing the load as well as an increase of revolution by the increment of the mains supply voltage.

**Load-current Limitation**

The total output load current is available at pin 6. It results in a voltage drop across $R_{11}$. When the potential of the load current reaches about 70% of the threshold value ($V_{T70}$), i.e., about 4.35 V at pin 6, it switches the high-load comparator and opens the switch between pins 11 and 12. By using an LED between these pins (11 and 12), a high-load indication can be realized.

If the potential at pin 6 increases to about 6.2 V ($= V_{T100}$), it switches the overload comparator. The result is programmable at pin 9 (operation mode).

**Mode Selection**

a) $\alpha_{\text{max}} (V_g = 0)$

In this mode of operation, pin 13 switches to $-V_S$ (pin 11) and pin 6 to GND (pin 10) after $V_6$ has reached the threshold $V_{T100}$. A soft-start capacitor is then shorted and the control angle is switched to $\alpha_{\text{max}}$. This position is maintained until the supply voltage is switched off. The motor can be started again with the soft-start function when the power is switched on again. As the overload condition switches pin 13 to pin 11, it is possible to use a smaller control angle, $\alpha_{\text{max}}$, by connecting a further resistance between pins 13 and 14.

b) Auto start (pin 9 – open), see Figure 12 on page 12

The circuit behaves as described above, with the exception that pin 6 is not connected to GND. If the value of $V_6$ decreases to 25% of the threshold value ($V_{T25}$), the circuit becomes active again with soft start.

c) $I_{\text{max}} (V_g = V_8)$, see Figure 14 on page 13

When $V_6$ has reached the maximum overload threshold value (i.e., $V_8 = V_{T100}$), pin 13 is switched to pin 8 ($V_{\text{Ref}}$) through the resistance $R (= 2 \, k\Omega)$ without the soft-start capacitor discharging at pin 7. With this mode of operation, direct load-current control ($I_{\text{max}}$) is possible.
# Absolute Maximum Ratings

Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Reference point pin 10, unless otherwise specified.

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<tr>
<th>Parameters</th>
<th>Pin</th>
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<th>Value</th>
<th>Unit</th>
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<td>-I_S</td>
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<td>mA</td>
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<td>0 - V_8</td>
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<td>mA</td>
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<td>mA</td>
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<td>Input voltages</td>
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<td>V</td>
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<td>Junction temperature range</td>
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<td>°C</td>
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<td>Ambient temperature range</td>
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<td>-10 to +100</td>
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## Thermal Resistance

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<th>Value</th>
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<td>SO16 on ceramic</td>
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### Electrical Characteristics

<table>
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<th>Parameters</th>
<th>Test Conditions</th>
<th>Pin</th>
<th>Symbol</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
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<td>-V_S</td>
<td>14.5</td>
<td>14.6</td>
<td>16.5</td>
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<td>-I_S = 30 mA</td>
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<td>-V_S</td>
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<td>16.8</td>
<td>V</td>
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<td>Current requirement</td>
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<td>-I_S</td>
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<td>-V_{Ref}</td>
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<td>-V_{Ref}</td>
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<td>-V_{Son}</td>
<td>11</td>
<td>11.3</td>
<td>12.3</td>
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<td>V_{out} = -1.2 V, Figure 6 on page 10</td>
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<td>150</td>
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<td>R_o - reference voltage</td>
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<td>%/K</td>
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<td>Pulse output current</td>
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<td>I_o</td>
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<td>125</td>
<td>150</td>
<td>mA</td>
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<td><strong>Soft Start, see Figure 8 on page 11 and Figure 9 on page 11</strong></td>
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<td>10</td>
<td>15</td>
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<td><strong>Mains Voltage Comensation see Figure 10 on page 12</strong></td>
<td></td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transfer gain</td>
<td>I_{15}/I_5</td>
<td>15/5</td>
<td>(1 and 2 open)</td>
<td>G_l</td>
<td>14</td>
<td>17</td>
<td>20</td>
</tr>
<tr>
<td>Output offset current</td>
<td>V_{(R6)} = V_{15} = V_5 = 0</td>
<td>12</td>
<td>±I_0</td>
<td>2</td>
<td>µA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Notes:**

- Note 1: All values are nominal and should be used in the design as a reference.
- Note 2: Refer to the manufacturer’s datasheet for detailed specifications.
- Note 3: Designs and applications involving power conversion should account for safety considerations.

---

**Figure References:**

- Figure 5: Voltage Monitoring
- Figure 6: Pulse output current
- Figure 7: Output pulse width
- Figure 8: Automatic Retriggering
- Figure 9: Soft Start
- Figure 10: Mains Voltage Complementation
- Figure 11: Soft Start and Mains Voltage Compensation
Load-current Detection, \( R_1 = R_2 = 3 \, k\Omega \), \( V_{15} = 0 \), \( V_6 = V_8 \), see Figure 11 on page 12

- **Transfer gain**: \( I_5/150 \, mV, I_6/150 \, mV \)
  - Symbol: \( G \)
  - Min.: 0.28
  - Typ.: 0.32
  - Max.: 0.37
  - Unit: \( \mu A/mV \)

- **Output offset currents**: \( I_1, I_2 = 100 \, \mu A \)
  - Symbol: \( -I_0 \)
  - Min.: 0
  - Typ.: 3
  - Max.: 6
  - Unit: \( \mu A \)

- **Reference voltage**: \( I_1, I_2 = 100 \, \mu A \)
  - Symbol: \( V_{Ref} \)
  - Min.: 300
  - Typ.: 400
  - Max.: 250
  - Unit: mV

- **Shunt voltage amplitude**: See Figure 2 on page 2
  - Symbol: \( \pm V_{(R6)} \)
  - Min.: 250
  - Max.: 250
  - Unit: mV

Load-current Limitation

- **High load switching**: Threshold \( V_{T70} \)
  - Figure 13 on page 13
  - Symbol: \( V_{T70} \)
  - Min.: 4
  - Typ.: 4.35
  - Max.: 4.7
  - Unit: V

- **Overload switching**: Threshold \( V_{T100} \)
  - Figure 14 on page 13
  - Symbol: \( V_{T100} \)
  - Min.: 5.8
  - Typ.: 6.2
  - Max.: 6.6
  - Unit: V

- **Restart switching**: Threshold \( V_{T25} \)
  - Figure 12 on page 12
  - Symbol: \( V_{T25} \)
  - Min.: 1.25
  - Typ.: 1.55
  - Max.: 1.85
  - Unit: V

Input current

- **Enquiry mode**: \( I_1 \)
  - Min.: 1
  - Unit: \( \mu A \)

Output impedance

- **Switching mode**: \( R_0 \)
  - Min.: 2
  - Typ.: 4
  - Max.: 8
  - Unit: k\Omega

Programming Input, see Figure 2 on page 2

- **Input voltage - auto-start**: \( V_9 = 3.8 \, V \)
  - Min.: 4.3
  - Max.: 4.7
  - Unit: V

- **Input current**: \( V_9 = 0 \) (non-max)
  - Symbol: \( -I_9 \)
  - Min.: 5
  - Typ.: 10
  - Max.: 20
  - Unit: \( \mu A \)

High Load Output, \( V_{T70} \), see Figure 13 on page 13, \( I_{12} = -3mA \)

- **Saturation voltages**: \( V_{T70} \)
  - Symbol: \( V_{sat} \)
  - Min.: 0.5
  - Max.: 1.0
  - Unit: V

Overload Output, \( V_{T100} \), \( V_9 = \) Open or \( V_9 = V_{10} \), see Figure 14 on page 13

- **Leakage current**: \( V_{T25} \)
  - Symbol: \( I_{kg} \)
  - Min.: 0.5
  - Unit: \( \mu A \)

- **Saturation voltages**: \( V_{T100} \)
  - Symbol: \( V_{sat} \)
  - Min.: 0.1
  - Unit: V

Output current, maximum load

- **Leakage current**: \( V_{T100} \)
  - Symbol: \( I_{kg} \)
  - Min.: 4
  - Unit: \( \mu A \)

- **Output impedance**: \( R_0 \)
  - Min.: 2
  - Typ.: 4
  - Max.: 8
  - Unit: k\Omega

Saturation voltage

- **Overload Output, \( V_{T100} \)**
  - Symbol: \( V_{13-8} \)
  - Min.: 100
  - Unit: mV
Diagrams

**Figure 5.** Ramp Control

![Figure 5. Ramp Control](image)

**Figure 6.** Pulse Output

![Figure 6. Pulse Output](image)
**Figure 7.** Output Pulse Width

![Graph showing output pulse width](image)

\[ \Delta t_p/\Delta C = 9 \mu s/nF \]

\[ t_p = (\mu s) \]

**Figure 8.** Soft-start Charge Current

![Graph showing soft-start charge current](image)

\[ V_S = 13 \text{ V} \]
\[ V_S = V_g \]

**Figure 9.** Soft-start Characteristic

![Graph showing soft-start characteristic](image)

\[ C_P = 10 \mu F \]
\[ V_S = -13 \text{ V} \]
\[ V_S = V_g \]
Figure 10. Mains Voltage Compensation

Figure 11. Load-current Detection

Figure 12. Restart Switching Auto Start Mode
Figure 13. High Load Switching (70%)

Figure 14. Overload Switching

Figure 15. Load Limitation
**Figure 16.** Power Dissipation of $R_1$

![Graph of Power Dissipation of $R_1$](image)

**Figure 17.** Power Dissipation of $R_1$ According to Current Consumption

![Graph of Power Dissipation vs. Current Consumption](image)

**Figure 18.** Maximum Resistance of $R_1$

![Graph of Maximum Resistance of $R_1$](image)
Figure 19. Application Circuit
### Ordering Information

<table>
<thead>
<tr>
<th>Extended Type Number</th>
<th>Package</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>U2010B-x</td>
<td>DIP16</td>
<td>Tube</td>
</tr>
<tr>
<td>U2010B-xFP</td>
<td>SO16</td>
<td>Tube</td>
</tr>
<tr>
<td>U2010B-xFPG3</td>
<td>SO16</td>
<td>Taped and reeled</td>
</tr>
</tbody>
</table>

### Package Information

**Package DIP16**

Dimensions in mm

- **20.0 max**
- **1.64**
- **1.44**
- **0.58**
- **0.48**
- **3.3**
- **4.8 max**
- **0.5 min**
- **3.3**
- **17.78**
- **9.75**
- **8.15**
- **7.82**
- **7.42**
- **6.4 max**
- **0.39 max**

**Alternative**

Technical drawings according to DIN specifications
Package SO16
Dimensions in mm

- Length: 10.0 mm
- Width: 9.85 mm
- Height: 3.7 mm

- Pin 1: 1.4 mm
- Pin 2: 0.4 mm
- Pin 3: 1.27 mm
- Pin 4: 8.89 mm
- Pin 5: 0.25 mm
- Pin 6: 0.10 mm
- Pin 7: 1.27 mm
- Pin 8: 8.89 mm
- Pin 9: 5.2 mm
- Pin 10: 4.8 mm
- Pin 11: 3.7 mm
- Pin 12: 3.8 mm
- Pin 13: 6.15 mm
- Pin 14: 5.85 mm

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