STSPIN L6470 and L6472

ST motor drivers are moving the future
The L6470 and L6472 ICs integrate a complex logic core providing a set of high-level features.

- Current control algorithms
- Microstepping
- Programmable speed profile
- Comprehensive command set
- Protections
The devices also integrate **analog circuitry** and a **dual full-bridge power stage** making it a stand-alone solution for stepper motor driving applications.

- **3 V Volt. Reg.**
- **16-MHz Oscillator**
- **SPI**
- **Thermal protection**
- **ADC**
- **Logic**
- **Charge pump**
- **Power stage**
- **DAC & Comp**
- **Current sensing**
L6470 and L6472 characteristics

- Supply voltage **from 8 to 45 V**
- Power stage
  - $3\ A_{RMS}$
  - $R_{DS(ON)} = 0.28\ \Omega$
- **Integrated current sensing**
  (no external shunt)
- **Up to 128 microsteps** (L6470)
- Current control
  - L6470: Voltage mode driving
  - L6472: Advanced current control
- **Sensorless stall detection** (L6470)
- **Digital Motion Engine**
  - Programmable speed profile
  - High-level commands
- **8-bit 5 MHz SPI interface**
  (Daisy-chain compatible)
- Integrated 16 MHz oscillator
- Integrated 5-bit ADC
- Integrated 3 V voltage regulator
- **Overcurrent, overtemperature and undervoltage protections**
- **HTSSOP and POWERSO packages**
Intelligence integration

Before L6470 and L6472 ...

System MCU

Dedicated MCU

Many digital + analog connections

stepper driver

+
Intelligence integration

with **L6470 and L6472** …

- System is greatly simplified
- No more dedicated MCU to perform speed profile and positioning calculations
- Less components
- Single MCU can drive more devices at the same time
A full-digital interface to MCU

- The fast SPI interface with **daisy-chain** capability allows a single MCU to manage multiple devices.

- Programmable alarm **FLAG** open-drain output for interrupt-based FW
  In daisy-chain configuration, **FLAG** pins of different devices can be OR-wired to save host controller GPIOs.

- **BUSY** open-drain output allows the MCU to know when the last command has been performed.
  In daisy-chain configuration, **BUSY** pins of different devices can be OR-wired to save host controller GPIOs.

- **BUSY** can be used as **SYNC** signal giving a feedback of the step-clock to the MCU
  (programmable # of microsteps)
Fully programmable speed profile boundaries

Speed

Maximum speed
from 15.25 to 15610 step/s
(15.25 step/s resolution)

Minimum speed
from 0 to 976 step/s
(0.24 step/s resolution)

Acceleration & Deceleration
from 14.55 to 59590 step/s²
(14.55 step/s² resolution)

Time
Move(N, DIR) command perform a motion of N steps in the selected direction. This command can be performed only when the motor is stopped.
Positioning features: Absolute positioning commands

**GoTo(Target)** command: reach the target position using shortest path.
This command can be performed only when motor is stopped or is running at constant speed.

**GoTo_DIR(Target, DIR)** command: reach the target position moving the motor in the selected direction.
This command can be performed only when the motor is stopped or is running at constant speed.
**Speed tracking features:**

**Constant speed command**

The `Run(SPD, DIR)` command drives the motor to reach the target speed `SPD` in the selected direction. Target speed and direction can be changed anytime.
At power-up, the load could be in an unknown position.
The absolute position counter should be initialized.

The **GoUntil** command moves the mechanical load to the limit switch position.

The **ReleaseSW** command moves the mechanical load on the limit switch triggering threshold.
Programmable overcurrent protection

Each MOSFET of the power stage is protected by an overcurrent protection system.

The overcurrent threshold can be programmed from 375 mA to 6 A.

When the current in one of the MOSFET exceeds the threshold, the whole power stage is immediately turned OFF.

The power stage cannot be enabled until a GetStatus command releases the failure condition.
The devices integrate a non-dissipative current sensing on each MOSFET.

The **overcurrent protection** is performed measuring the current in each MOSFET.

The **stall detection (L6470)** and **current control (L6472)** are performed using the **low-side MOSFETs** current value.
Warning temperature and thermal shutdown

- **Safe region**: Normal operation is restored.
- **Thermal shutdown**: The power stage is disabled and cannot be turned on in any way.
- **Warning region**: The device operates normally but it is approaching the thermal shutdown temperature.

\[
T_{j} \quad T_{SD} \quad T_{WRN}
\]

- \( T_{j} \): Junction temperature
- \( T_{SD} \): Thermal shutdown temperature
- \( T_{WRN} \): Warning temperature
The devices integrate a diagnostic register collecting the information about the status of the system:

- Power stage enabled/disabled
- Command under execution (BUSY)
- Motor status (direction, acc., dec., etc.)
- Step-clock mode
- Overcurrent
- Thermal status
- Undervoltage (it also indicates the power-up status)
- Stall detection
- SW status
- SW input falling edge (limit switch turn-on)
- Incorrect or not performable command received
Programmable output slew-rate

Four output slew-rate values can be selected via SPI in order to fit the application EMI / Power dissipation tradeoff.
L6470
Voltage mode driving
BEMF compensation

Without BEMF compensation

Motor speed

KVAL

SPEED

Applied phase voltage

With BEMF compensation

KVAL

SPEED

V_phase

BEMF

Resulting phase current

I_phase
BEMF compensation

Starting amplitude:
The “zero speed” amplitude of the output sinewave

BEMF compensation parameters:
- Starting amplitude
- Starting comp. slope
- Final comp. slope
- Intersect speed

Motor speed

Intersect speed:
Speed at which the compensation curve slope switches from starting to final value

Starting comp. slope:
The slope of compensation curve when speed is lower than the Intersect speed

Amplitude

Final comp. slope:
The slope of compensation curve when speed is greater than the Intersect speed

Sinewave amplitude
According to motor conditions (acc/deceleration, constant speed, hold), a different torque, and then current, could be needed.
BEMF compensation
Supply voltage compensation

The voltage sinewaves are generated through a PWM modulation. As a consequence, the actual phase voltage depends on the supply voltage of the power stage.
Supply voltage compensation

Compensation algorithm calculates the correction coefficient

\( V_S + n(t) \)

5-bit ADC measures the actual motor supply voltage

Compensation coefficient is applied to the sinewave amplitude

\( V_{OUT} \)
Sensorless stall detection

Using integrated current sensing and the adjustable STALL current threshold, a cheap and easy stall detection function can be implemented.
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Using integrated current sensing and the adjustable STALL current threshold, a cheap and easy stall detection function can be implemented.

STALL!
BEMF is null and current is suddenly increased
Sensorless stall detection limitations

Stall detection performances can be reduced in the following conditions:

• **Low speed**
  (negligible BEMF value)

• **High speed**
  (current can be low due to the low-pass filtering effect of the inductor)
Slow speed optimization

- During low-speed movements, the sinewave current could suffer from zero-crossing distortion. As result, **the motor rotation is discontinuous**.

- New low-speed optimization algorithm heavily reduce the distortion. **Smoothness of the driving is increased**.
L6472
Advanced current control
Advanced current control

• **Automatic selection of the decay mode**
  Stable current control in microstepping

• **Slow decay and fast decay balancing**
  Reduced current ripple

• **Predictive current control**
  Average current control
Challenges to perform the right decay

During the OFF state, both slow and fast decay must be used for a better control:

L6472 performs an AUTO-ADJUSTED DECAY
**Auto-adjusted decay**

Target Current level

- **tON1 < TON_MIN**
- **tON2 > TON_MIN**

Fast decay for
```
tOFF,FAST = TOFF_FAST/8
```
in order to remove more energy than a slow decay

Slow decay for \( tOFF = TSW(\star) \)

<table>
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<td>Maximum fast decay duration</td>
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<tr>
<td>TSW</td>
<td>Fixed OFF time(* )</td>
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(\* ) No predictive control
Auto-adjusted decay

Target Current level

- **tON1**: tON1 < TON_MIN
- **tOFF,FAST1**: Fast decay for tOFF,FAST1 = TOFF_FAST/8

- **tON2**: tON2 < TON_MIN
- **tOFF,FAST2**: Fast decay for tOFF,FAST2 = TOFF_FAST/4

- **tON3**: tON3 > TON_MIN
- **tOFF,FAST3**: Mixed decay:
  - tOFF3 = TSW (*)
  - tOFF,FAST3 = tOFF,FAST2 = TOFF_FAST/4
  - tOFF,Slow = tOFF3 – tOFF,FAST3

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(*) No predictive control
Fast decay for $t_{FALL1} = \text{FAST\_STEP}/4$

$t_{FALL2} = \text{FAST\_STEP}/2$

$t_{FALL3} = \text{FAST\_STEP}/2$

$t_{FALL3} = \text{last FAST\_STEP}$

In our case:

$t_{FALL3} = \text{FAST\_STEP}/2$

**Parameter** | **Function**
---|---
$\text{TON\_MIN}$ | Target minimum ON time
$\text{FAST\_STEP}$ | Maximum fast decay duration during falling steps
Predictive current control: average current

The extra on time is calculated cycle-by-cycle using the following formula:

\[ t_{\text{PRED}}^n = \frac{(t_{\text{ON}}^{n-1} + t_{\text{ON}}^n)}{2} \]

**Note:** The TON_MIN limit of the current control is checked on \( t_{\text{ON}} \) time only. If \( t_{\text{ON}} < \text{TON\_MIN} \), no extra on time is performed and the decay adjustment sequence is performed.
Predictive current control: average current

When the system reaches the stability $\rightarrow t_{\text{PRED}n} = t_{\text{ON}n}$

In this case the average current is equal to the reference: the system implements a control of the average value of the current.
Predictive current control: switching freq.

The current is increased on-time of t_{PRED1} is performed

Extra on-time of t_{PRED1} is performed

The new off time is evaluated according to t_{PRED1} value:
\[ t_{OFF2} = TSW - (t_{PRED1} \times 2) \]

Considering
\[ t_{ONn} = t_{PREDn} \approx t_{PRED1} \]
\[ t_{PWM2} \approx (t_{PRED1} \times 2) + t_{OFF2} = TSW \]
Typical application

- Minimal component count
- MCU needs only **1 SPI interface** and **2-4 optional GPIOs**
Competitive advantages

• High level of integration
• Integrated current sensing
• Advanced diagnostics
• Stand-alone solution
• Suitable for multi-motor applications

Further information and full design support can be found at www.st.com/stspin