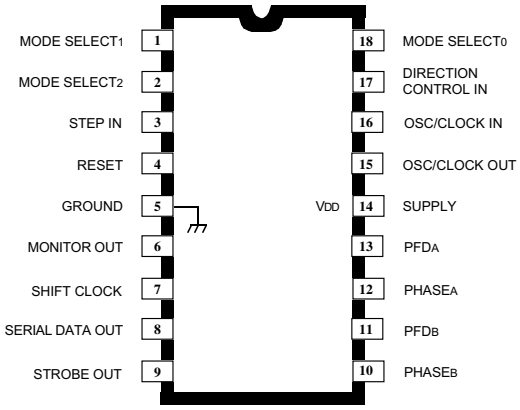
4255

Data Sheet
26113

8-BIT MICROCONTROLLER

A4255CA



Dwg. PP-071A

ABSOLUTE MAXIMUM RATINGS

Supply Voltage, V_{DD} ..... **7.0 V**

Input Voltage Range,
V_I ..... **-0.3 V to V_{DD} + 0.6 V**

RESET Voltage, V_{RESET} ..... **14 V**

Input Clamp Current, I_{IK} ..... **±20 mA**

Output Clamp Current, I_{OK} ..... **±20 mA**

Operating Temperature Range,
T_A ..... **0°C to +70°C**

Storage Temperature Range,
T_S ..... **-55°C to +150°C**

Caution: These CMOS devices have input static protection (Class 3) but are still susceptible to damage if exposed to extremely high static electrical charges.

The A4255CA and A4255CLN microcontrollers make designing with step motors easy, inexpensive, and productive. A reference design technique is integral to the implementation of a system that includes the power circuitry, a low-cost, 8-bit, preprogrammed microcontroller and the other components needed to complete the control hardware. The A4255Cx eliminates the need for software development, expedites the product creation, and hastens the time to market.

The reference design can be utilized directly or integrated into a larger printed wiring board. A further benefit is the compactness of the circuit layout. Power-driver output ratings presently available with these devices are 50 V and ±1.5 A (with the A3955 or A3957). A similar device for 46 V and either 1.5 A (with the SLA7042M) or 3 A (with the SLA7044M) is planned. The reference design supports stepping formats that include full-step, half-step, quarter-step, eighth-step, and sixteenth-step (microstepping) increments for a two-phase stepping motor.

The A4255CA is furnished in an 18-pin dual in-line plastic package for through-hole applications. The A4255CLN is furnished in a 20-lead wide-body, shrink-pitch, small-outline plastic package (SSOP) with gull-wing leads for minimum area, surface-mount applications.

FEATURES

- Full-, Half-, Quarter-, Eighth-, or Sixteenth-Step Increments
- DC to 20 MHz Clock Input
- Power-On Reset
- Brown-Out Reset
- High-Speed CMOS Technology
- Low Power, <20 mA @ 5 V, 20 MHz (Typically 9 mA)

Always order by complete part number:

Part Number	Package
A4255CA	18-pin DIP
A4255CLN	20-lead shrink-pitch SOIC

4255
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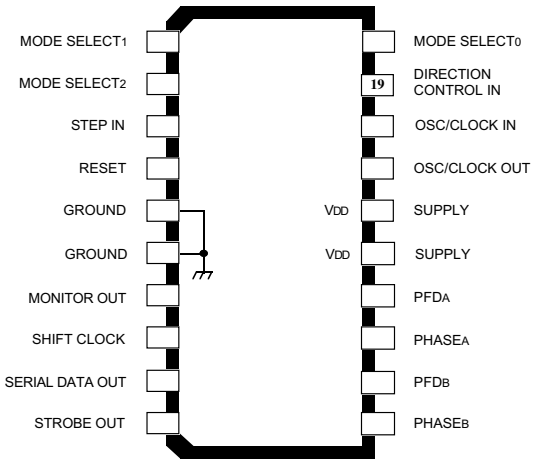
MICROCONTROLLER

A4255CLN

0.65 mm (0.026") pitch



Dwg. PP-071-1

RECOMMENDED OPERATING CONDITIONS

over operating temperature range

Logic Supply Voltage Range, V_{DD} ..... 4.5 V to 5.5 V
High-Level Input Voltage, V_{IH} ..... $\geq 0.85V_{DD}$
Low-level input voltage, V_{IL} ..... $\leq 0.15V_{DD}$

FUNCTIONAL DESCRIPTION

To ease and simplify the design effort, the user only provides the following signals: (a) direction, (b) stepping clock (8x the full-step frequency), (c) mode logic (three inputs determine the operation for full, half, quarter, or eighth stepping), (d) reset input (initiates a 'detent' position), and (e) recirculation control (this allows establishing the percent of fast- vs slow-decay in the phase winding). The microcontroller program providess automatic recirculation control. This eliminates the need for evaluating the impact of stepping rate vs the sinusoidal current profile.

Although recirculation control can provide slight improvements (i.e., lower current ripple, reduced motor heating [a few degrees], and diminish audible noise levels [minimal differences]), this entails an evaluation of the motor (and step frequencies) to determine the proper ratio of fast- and slow-decay. The benefits of tuning the recirculation ratios are small, and the time and effort required can be considerable. Hence, the uninitiated user should opt for the automatic recirculation control, and avoid the essentially unnecessary activity.

MICROCONTROLLER OPERATION

Although 'hardware' control of the microstepping ICs is feasible, without a specific (ASIC), monolithic IC controller the prime solution becomes a 'software' option. From the user's perspective, a 'preprogrammed' microcontroller appears little, or no, different than a 'dedicated' controller and sequencer IC expressly created for microstepping applications of the power-driver ICs. Further, the flexibility of a software-based drive is certainly a basic benefit (high-volume production of 8-bit microcontrollers transposes to low-cost circuitry).

As an indicator of the logic signals needed to control the power ICs, Table 1 lists the required A3955 inputs to the 3-bit DAC for eighth-step operation (the similar A3957 uses a 4-bit DAC for sixteenth-step operation). These I/O signals are serial data from the microcontroller, then converted to a parallel mode by a 74HC595 as the 'interface' between the microcontroller and the two microstepping power ICs.

The versatility offered by software control allows the operating modes listed in Table 1. This table itemizes the various logic inputs that determine direction, stepping

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FUNCTIONAL DESCRIPTION (cont'd)

format, reset, 1/8th vs 1/16th sub-steps, etc. Note that during power up, shift clock (SCLK) is sampled for a pull-up or pull-down resistor to establish the fractional step limit. A pull up sets up a 1/8th-step format (for the A3955) and pull down sets up 1/16th-operation (for the A3957).

Table 2 lists the microcontroller terminal descriptions and provides the essence of the circuit operation (a schematic illustrating a typical stepper design follows). A brief description of the microcontroller I/O should clarify the connections of the various elements of the drive electronics.

Table 1 — Controller/sequencer IC operational logic

Binary inputs				Operating mode	Comments
DIR	MS2	MS1	MS0	(Command executed on L → H of CLK)	(Applicable power ICs)
0	0	0	0	CW, Full step (single-phase)	A3955/57
0	0	0	1	CW, Half step (constant torque)	A3955/57
0	0	1	0	CW, 1/4 step (constant torque)	A3955/57
0	0	1	1	CW, 1/8th step (constant torque)	A3955/57
0	1	0	0	CW, 1/16th step (constant torque)	A3957 only
0	1	0	1	Disable A3955/57 holding torque	At present position
0	1	1	0	Enable A3955/57 holding torque	From present position
0	1	1	1	Reset A4255 sequencer IC	A3955/57
1	0	0	0	CCW, full step (single-phase)	A3955/57
1	0	0	1	CCW, half step (constant torque)	A3955/57
1	0	1	0	CCW, 1/4 step (constant torque)	A3955/57
1	0	1	1	CCW, 1/8th step (constant torque)	A3955/57
1	1	0	0	CCW, 1/16th step (constant torque)	A3957 only
1	1	0	1	Disable A3955/57 holding torque	At present position
1	1	1	0	Enable A3955/57 holding torque	From present position
1	1	1	1	Reset A4255 sequencer IC	A3955/57

FUNCTIONAL DESCRIPTION (cont'd)

Table 2 — Microcontroller terminal descriptions

A4255CA DIP	A4255CLN SSOP	Function	Description	Comments, connections, etc.
1	1	Input	Mode select 1	Static and/or dynamic control of stepping mode
2	2	Input	Mode select 2	Static and/or dynamic control of stepping mode
3	3	Input	Step in	Governs full-step rate (÷8 for A3955; ÷16 for A3957)
4	4	Input	Reset	Resets DIR., MS2, MS1, and MS0 to 0000 (detent)
5	5, 6	Power	Ground	Logic power return
6	7	Output	Monitor out	Signals full-step rotor alignment (active low)
7	8	I/O	Shift clock	Pull up for A3955; pull down for A3957
8	9	Output	Serial data out	Shifts 8-bit serial data to 74HC595 serial input
9	10	Output	Strobe out	Latches 8-bit data into 74HC595 (latch clock in)
10	11	Output	Phase B	Controls current direction in phase B
11	12	Output	PFD B	Phase B recirculation control
12	13	Output	Phase A	Controls current direction in phase A
13	14	Output	PFD A	Phase A recirculation control
14	15, 16	Power	Supply	(V_{DD}) Recommended range: 4.5 V to 5.5 V
15	17	Output	Osc/clock out	Crystal oscilator connection
16	18	Input	Osc/clock in	Crystal oscillator connection/external clock input
17	19	Input	Direction control	Determines direction of step motor rotation
18	20	Input	Mode select 0	Static and/or dynamic control of stepping mode

Mode-select inputs

These three inputs (MS2, MS1, and MS0) determine the stepping format, disable/enable motor power, and reset the controller/sequencer. In conjunction with the direction input, the mode inputs control the sixteen operating states listed. Deactivating stepper power in any position except 'detent' (i.e., a single phase activated) results in the motor rotor advancing, or retracting, from its intermediate position and alignment with a natural (i.e., minimum-reluctance flux field) orientation. The absolute position may be affected by inertia, load, fractional position, ringing, etc. and cannot be determined without feedback. Phase currents must be maintained to immobilize the rotor/load in any intermediate position.

Step (clock) input

The sequencer stepping-clock frequency is a multiple of the actual stepping rate. The A3955 requires a stepping-clock input frequency equal to eight times the intended stepping rate for the motor; the A3957 requires a stepping clock rate that is sixteen times the actual stepping rate of the motor. However, neither design necessitates that the step frequency be varied should the operating mode(s) be switched during operation. Shifting from one stepping format does not mandate a simultaneous (and equivalent) change in the clock frequency.

Using a 20 MHz crystal (maximum limit for the A4255) allows a 50 kHz stepping clock for the A3955, and this equates to 6 250 full steps per second (50 kHz/8). For the A3957 this 50 kHz stepping clock translates to

FUNCTIONAL DESCRIPTION (cont'd)

3 125 full steps per second (50 kHz/16). These frequencies represent the attainable limits with the A4255.

Although not a necessity, a stepping clock with a 50% duty cycle represents the simplest technique for providing an appropriate (≤50 kHz) stepping clock rate. The step clock varies depending upon the start, acceleration, slewing, deceleration, and stop trajectories mandated by the motion system control and 'point-to-point' timing objectives.

Reset input

The preprogrammed microcontroller incorporates two 'software' reset states that are serially loaded with MS2, MS1, and MS0 all high. However, the direct hardware reset is actuated with a logic 0 (active low) on this input An input low level defaults to the 0000 binary state and sets the rotor to its natural (or detent) position with one-phase energized.

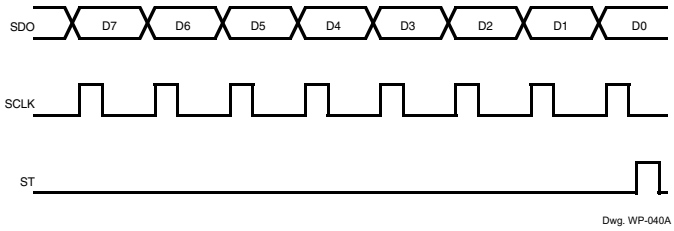
Monitor output

An output low signal indicates a rotor alignment corresponding to a single phase on position. Any changes in the operating mode (microstepping to full-step, etc.) should coincide with the interval that the monitor output is in the low state. This alleviates noise problems, excessive ringing, etc. that may result from changing the stepping modes on-the-fly. Nonlinear (such as S-curve) acceleration profiles can exploit this signal to achieve very smooth, quiet stepper operation.

Shift clock output

This I/O terminal serves a dual purpose. On power up, the microcontroller samples this terminal as an input. Connecting a pull-up resistor results in 1/8th-step format; while a pull-down resistor configures the controller for its 1/16th-step mode (A3957 only). This provides versatility, simplicity, and cost-effectiveness for most users.

Operating in its output mode, this I/O constitutes the shift clock signal for the 74HC595. Data is transferred from the microcontroller serial-data output to the serial-data input of the 74HC595. This 8-bit serial format is converted into parallel signals controlling the 3-bit (or 4-bit) DAC input lines to the two microstepping power ICs. Serial data from the serial data output is valid on the low-to-high clock transitions and eight clock pulses shift serial control signals into the 74HC595. A basic timing diagram (showing serial data, shift clock, and strobe) is depicted. Signal timing is controlled by the preprogrammed microcontroller; data entered into the 74HC595 shift register is then latched by the low-to-high transition of the strobe input.



Serial data, shift clock, and strobe

Serial data output

The binary signal instructions that control each of the microstepping power ICs is shown in table 1. The first 3-bits (or 4-bits) control the digital-to-analog conversion in one power IC, while the next 3 (or 4-bits) ratio the second power driver current. The microcontroller monitors all the various static inputs (i.e., Direction, Mode Selects, Reset), and by exploiting the Stepping Clock for its input frequency, transfers the 8-bit data commands to the power driver ICs via the serial-to-parallel interface IC. The microcontroller utilizes look-up tables to provide overall control of direction, stepping format, and recirculation mode (PFD). The microcontroller reads inputs and then outputs time-based signals to control both microstepping ICs.

Strobe output

After the 8-bit serial data has been loaded into the shift register, a low-to-high transition on the strobe output transfers the serial data from the shift register into the eight 'D' flip-flops that compose the parallel-data outputs. This 'latched' data controls microstepping current ratios for both power ICs, and is 'updated' after eight step clocks.

FUNCTIONAL DESCRIPTION (cont'd)

Direction control outputs

Two of the microcontroller outputs are devoted to direction control. The direction signals follow the sequencing to provide the 1/8th-step 'sinusoidal' waveforms. Direction outputs are parallel, and connected directly to the power IC inputs (A3955 in the schematic). Obviously, both direction signals must coincide with the 8-bit serial-to-parallel conversion signals that control the phase current ratios (D2, D1, and D0).

PFD control outputs

Another pair of microcontroller outputs constitute parallel, direct control of the recirculation paths during each PWM current cycle. The percentage of fast-decay (or four-quadrant) to slow-decay (or two-quadrant) recirculation determines how effectively the output current tracks a sinusoidal waveform. Mixed-mode operation was utilized for those portions of each microstepping cycle in which the current is decreasing. The application of mixed-mode decay allows the PWM current to properly decay during each fixed-off-time interval.

The typical application shown includes a pair of 49.9 kΩ variables and allows setting the ratios of fast- and slow-decay to match the individual characteristics of the step motor, step frequency, supply voltage, etc. As the stepping frequency is increased, waveform anomalies become more pronounced, and the benefit of mixed mode (or fast decay) also becomes very noticeable.

A comprehensive discussion of mixed-mode operation is included in Allegro Technical Paper STP 97-5.

Oscillator input/clock input

This device connection serves as one terminal for a parallel-cut crystal (oscillator 2 is the other). In the typical application, two 20 pF capacitors are recommended, and a series resistor from oscillator out may be required if AT-cut crystals are utilized.

Also, this terminal is used if an external clock (from a system computer, etc.) is connected here in lieu of a crystal or ceramic resonator. If so, the oscillator out connection is left open. The 20 MHz frequency limit applies to using any clock source.

Oscillator output/clock output

This is the other device connection used for the internal crystal oscillator (or ceramic resonator) that supplies the microcontroller with an oscillator/time base (≤20 MHz).

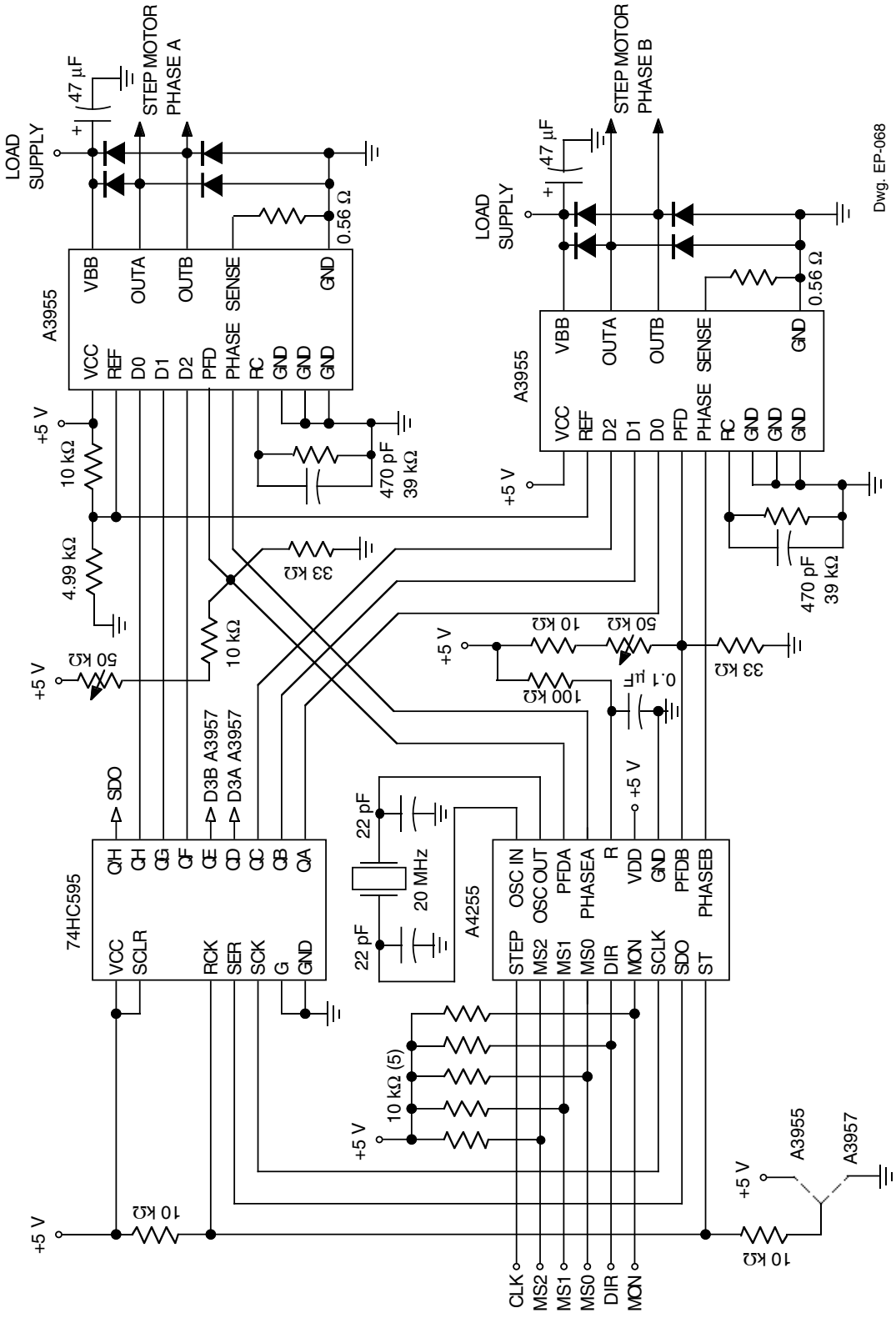
Direction input

This input controls the sequencing of the winding currents. Reversing direction may necessitate deceleration (perhaps full stop) to avoid problems associated with the load inertia causing the motor to overshoot the proposed stop/reverse position.

A more extensive discussion of this microcontoller and microstepping is included in Allegro Technical Paper STP 99-11.

CONTROL OF PHASE CURRENTS

The power-driver ICs regulate the winding currents, and the user establishes the design value via a stable voltage reference and a current-sensing resistor for each winding (R_8 and R_{19}).



Low-cost microstepping drive circuitry

This "typical" application is available as a product evaluation kit (APEK3955SLB-02)

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