3-Phase Brushless DC Motor Controller

Features

- Hall-Effect Commutation
- 60° or 120° Sensor Spacing
- Integral High-Side Drive for all N-Channel MOSFET Bridges
- PWM Input
- Quadrature Selection
- Tachometer Output
- Reversible
- Braking
- Output Enable Control
- Cross Conduction Protection
- Current Limiting
- Undervoltage Lockout
- Internal Pull-Up Resistors

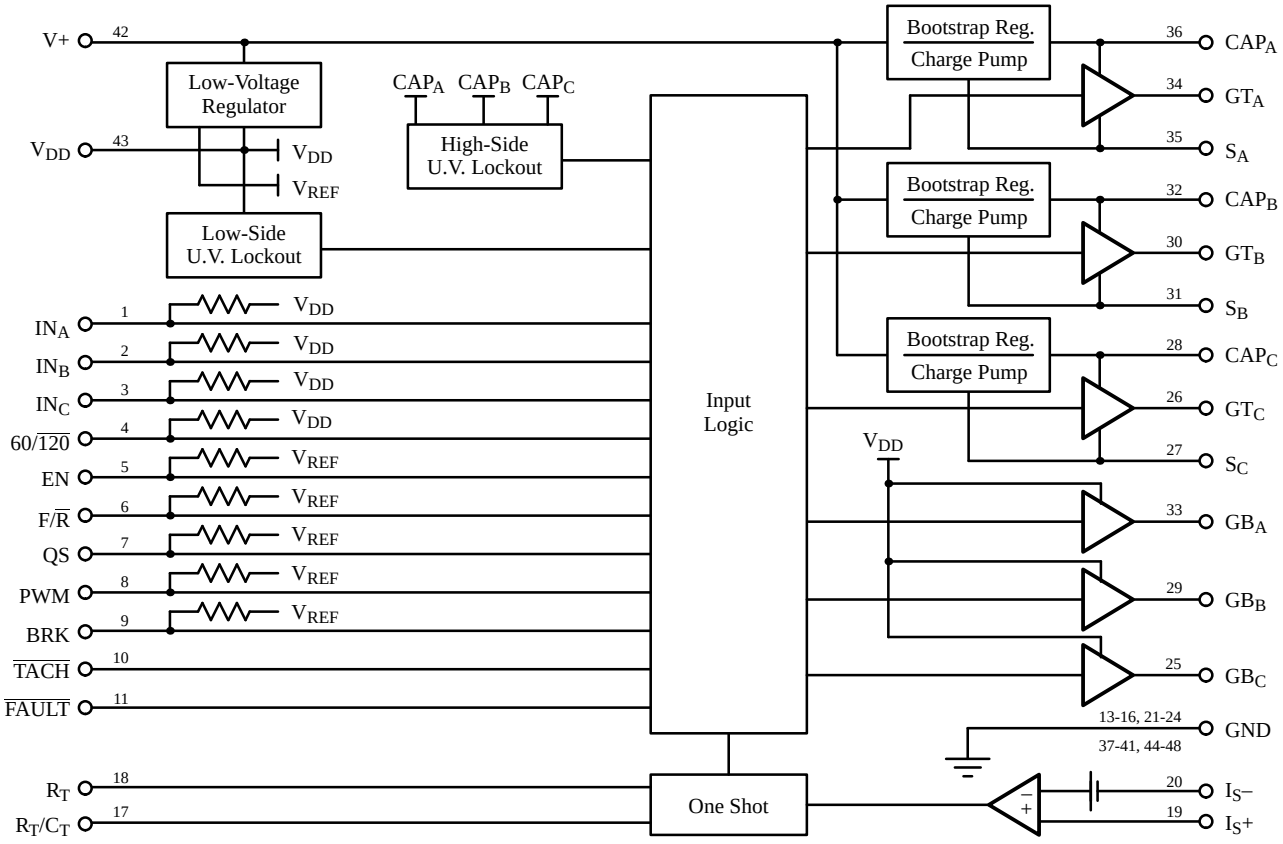
Description

The Si9979CS is a monolithic brushless dc motor controller with integral high-side drive circuitry. The Si9979 is configured to allow either 60°or 120° commutation sensor spacing. The internal low-voltage regulator allows operation over a wide input voltage range, 20- to 40-V dc.

The Si9979CS provides commutation from Hall-effect sensors. The integral high-side drive, which utilizes combination bootstrap/charge pump supplies, allows implementation of an all n-channel MOSFET 3-phase bridge. PWM, direction, quadrature select, and braking inputs are included for control along with a tachometer output. Protection features include cross conduction protection, current limiting, and undervoltage lockout. The $\overline{\text{FAULT}}$ output indicates when undervoltage, over current, disable, or invalid sensor shutdown has occurred.

The Si9979CS is specified to operate over the commercial (0°C to 70°C) temperature range.

Functional Block Diagram



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Absolute Maximum Ratings

Voltage on Pin 42 . . . . . 50 V
Voltage on Pins 1–4, 10, 11 . . . . . –0.3 V to V_{DD} + 0.3 V
Voltage on Pins 5–9 . . . . . –0.3 V to 5.5 V
Voltage on Pins 26, 28, 30, 32, 34, 36 . . . . . 60 V
Voltage on Pins 27, 31, 35 . . . . . –2 to 50 V

Operating Temperature . . . . . 0 to 70°C
Storage Temperature . . . . . –65 to 150°C
Junction Temperature (T_J) . . . . . 150°C
Power Dissipation (P_D) . . . . . 0.7 W

Recommended Operating Range

V+ . . . . . +20 to 40 V_{DC}
R_T . . . . . 10 kΩ Min

Specifications

Parameter	Symbol	Specific Test Conditions V+ = 20 to 40 V	Limits C Suffix: 0 to 70°C Min[a]	Typ[b]	Max[a]	Unit
Power						
Supply Voltage Range	V+		20		40	V
Logic Voltage	V_{DD}	–20 mA ≤ I_{DD} ≤ 0 mA	14.5	16	17.5	
Supply Current	I+	I_{DD} = 0 mA		4.5		mA
Logic Current	I_{DD}		–20			
Commutation Inputs (IN_A, IN_B, IN_C, 60/$\overline{120}$)						
High-State	V_{IH}		4.0			V
Low-State	V_{IL}				1.0	
High-State Input Current	I_{IH}	V_{IH} = V_{DD}			10	µA
Low-State Input Current	I_{IL}	V_{IL} = 0 V		–50		
Logic Inputs (F/$\overline{R}$, EN, QS, PWM, BRK)						
High-State	V_{IH}		2.0			V
Low-State	V_{IL}				0.8	
High-State Input Current	I_{IH}	V_{IH} = 5.5 V			10	µA
Low-State Input Current	I_{IL}	V_{IL} = 0 V		–125		
Outputs						
Low-Side Gate Drive, High State	V_{GBH}		14	16	17.5	V
Low-Side Gate Drive, Low State	V_{GBL}				0.1	
High-Side Gate Drive, High State	V_{GTH}			16	18	
High-Side Gate Drive, Low State	V_{GTL}				0.1	
Low-Side Switching, Rise Time	t_{rL}	Risetime = 1 to 10 V **Falltime = 10 to 1 V** C_L = 600 pF		70		ns
Low-Side Switching, Fall Time	t_{fL}			25		
High-Side Switching, Rise Time	t_{rH}			100		
High-Side Switching, Fall Time	t_{fH}			40		
Break-Before-Make Time	t_{BLH}			100		
	t_{BHL}			300		
$\overline{TACH}$ Output/$\overline{FAULT}$ Output	V_{OL}	I_{OL} = 1.0 mA		0.15	0.4	V
$\overline{TACH}$ Output Pulsewidth	t_T		300	600		ns

Specifications

Parameter	Symbol	Specific Test Conditions V+ = 20 to 40 V	Limits C Suffix: 0 to 70°C Min[a]	Typ[b]	Max[a]	Unit
Protection						
Low-Side Undervoltage Lockout	UVLL			12.2		V
Low-Side Hysteresis	V_H			0.8		
High-Side Undervoltage Lockout	UVLH	$S_{A, B, C}$ = 0 V		V_{DD} – 3.3		
Current Limit						
Comparator Input Bias Current	I_{IB}		–5			µA
Comparator Threshold Voltage	V_{TH}		90	100	110	mV
Common Mode Voltage	V_{CM}		0		1	V
One Shot Pulse Width	t_p	R_T = 10 k C_T = 0.001 µF	8	10	12	µs
		R_T = 10 k C_T = 0.01 µF	80	100	120	

Notes
a. The algebraic convention whereby the most negative value is a minimum and the most positive a maximum.
b. Typical values are for DESIGN AID ONLY, not guaranteed nor subject to production testing.

Commutation Truth Table

Inputs										Outputs							Conditions
Sensors (60°Spacing)			Sensors (120°Spacing)							Top Drive			Bottom Drive				
IN_A	IN_B	IN_C	IN_A	IN_B	IN_C	EN	F/$\overline{R}$	BRK	I_S+	GT-A	GT-B	GT-C	GB-A	GB-B	GB_C	$\overline{FAULT}$	
0	0	0	1	0	1	1	1	0	0	1	0	0	0	1	0	1	
1	0	0	1	0	0	1	1	0	0	1	0	0	0	0	1	1	
1	1	0	1	1	0	1	1	0	0	0	1	0	0	0	1	1	
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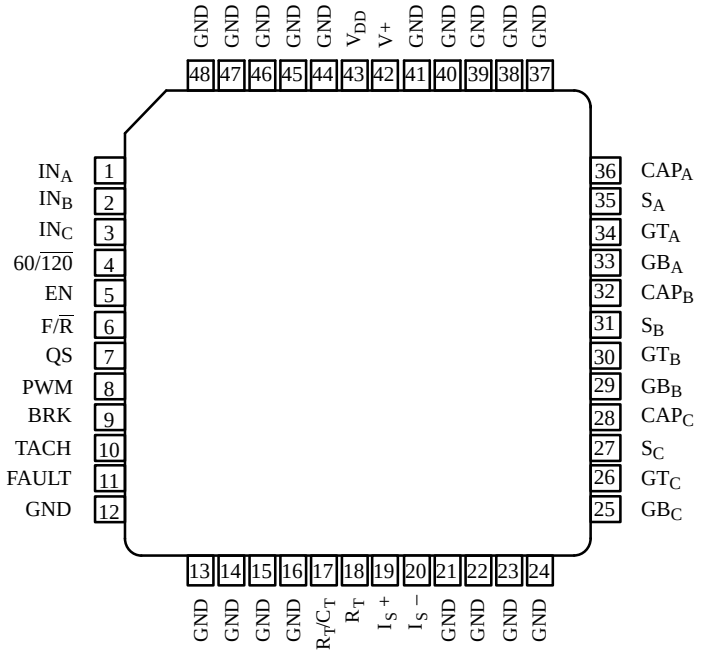
X	X	X	X	X	X	0	X	0	X	0	0	0	0	0	0	0	Disable
X	X	X	X	X	X	0	X	1	X	0	0	0	1	1	1	0	Power Down
L	L	L	L	L	L	1	X	1	0	0	0	0	1	1	1	1	Brake
L	L	L	L	L	L	1	X	1	1	0	0	0	1	1	1	0	Over I in BRK
L	L	L	L	L	L	1	X	0	1	0	0	0	0	0	0	0	Over I
1	0	1	1	1	1	1	X	0	X	0	0	0	0	0	0	0	
1	0	1	1	1	1	1	X	1	X	0	0	0	1	1	1	0	
0	1	0	0	0	0	1	X	0	X	0	0	0	0	0	0	0	
0	1	0	0	0	0	1	X	1	X	0	0	0	1	1	1	0	

Notes: L. Any valid sensor combination
X. Don't care

Pin Configuration

SQFP-48



Top View

Pin Description

Pins 1–3: IN_A, IN_B, IN_C

IN_A, IN_B, and IN_C are the commutation sensor inputs, and are intended to be driven by open collector Hall effect switches. These inputs have internal pull up resistors tied to V_{DD}, which eliminates the need for external pull up resistors.

Pin 4: 60/$\overline{120}$

The 60/$\overline{120}$ input allows the use of the Si9979 with either a 60° or 120° commutation sensor spacing. An internal pull up resistor, which is tied to V_{DD}, sets the default condition to 60° spacing. 120° spacing is selected by pulling this input to ground.

Pin 5: EN (Enable)

A logic “1” on this input allows commutation of the motor. This is the default condition as this pin is pulled up internally. When this pin is pulled to ground, all gate drive outputs are turned off.

Pin 6: F/$\overline{R}$ (Forward/Reverse)

A logic “1” on this input selects commutation for motor rotation in the “forward” direction. This is the default condition as this pin is pulled up internally. When this pin is pulled to ground, the commutation sensor logic levels are inverted internally, causing reverse rotation.

Pin 7: QS (Quadrature Select)

This input determines whether the bottom MOSFETs or both bottom and top MOSFETs switch in response to the PWM signal. A logic “1” on this input enables only the bottom MOSFETs. This is the default condition as this pin is pulled up internally. When this pin is pulled to ground, both the bottom and top MOSFETs are enabled.

Pin 8: PWM

An open collector (drain) or TTL compatible signal is applied to this input to control the motor speed. The QS input determines which MOSFETs are switched in response to the PWM signal. If no PWM signal is being used, this input is left open. It is pulled up internally, which allows the MOSFETs to follow the commutation sequence.

Pin Description (Cont'd)

Pin 9: BRK

With this input at logic "1", the top MOSFETs are turned off and the bottom MOSFETs are turned on, shorting the motor windings together. This provides a braking torque which is dependent on the motor speed. This is the default condition as this pin is pulled up internally. When this pin is pulled to ground, the MOSFETs are allowed to follow the commutation sequence.

Pin 10: $\overline{\text{TACH}}$

This output provides a minimum 300-nanosecond output pulse for every commutation sensor transition, yielding a 6 pulse per electrical revolution tachometer signal. This output is open drain.

Pin 11: $\overline{\text{FAULT}}$

The $\overline{\text{FAULT}}$ output switches low to indicate that at least one of the following conditions exists, controller disable ($\overline{\text{EN}}$), undervoltage lockout, invalid commutation sensor code shutdown, or overcurrent shutdown. This output is open drain.

Pin 17: R_T/C_T

The junction of the current limit one shot timing resistor and capacitor is connected to this pin. This one-shot is triggered by the current limit comparator when an overcurrent condition exists. This action turns off all the gate drives for the period defined by R_T and C_T, thus stopping the flow of current.

Pin 18: R_T

One side of the current limit one shot timing resistor is connected to this pin.

Pin 19: I_S+

This is the sensing input of the current limit comparator and should be connected to the positive side of the current sense resistor. When the voltage across the current sense resistor exceeds 100 mV, the comparator switches and triggers the current limit one-shot. The one-shot turns off all the gate drives for the period defined by R_T and C_T, thus stopping the flow of current. If the overcurrent condition remains after the shutdown period, the gate drives will be held off until the overcurrent condition no longer exists.

Pin 20: $I_S–$

This pin is the ground reference for the current limit comparator. It should be connected directly to the ground side of the current sense resistor to enhance noise immunity.

Pins 12–16: 21–24, 37–41, 44–48, GND

These pins are the return path for both the logic and gate drive circuits. Also, they serve to conduct heat out of the package, into the circuit board.

Pin 25: GB_C

This is the gate drive output for the bottom MOSFET in Phase C.

Pin 26: GT_C

This is the gate drive output for the top MOSFET in Phase C.

Pin 27: S_C

This pin is negative supply of the high-side drive circuitry. As such, it is the connection for the negative side of the bootstrap capacitor, the top MOSFET Source, the bottom MOSFET Drain, and the Phase C output.

Pin 28: CAP_C

This pin is the positive supply of the high-side circuitry. The bootstrap capacitor for Phase C is connected between this pin and SC.

Pin 29: GB_B

This is the gate drive output for the bottom MOSFET in Phase B.

Pin 30: GT_B

This is the gate drive output for the top MOSFET in Phase B.

Pin 31: S_B

This pin is negative supply of the high-side drive circuitry. As such, it is the connection for the negative side of the bootstrap capacitor, the top MOSFET Source, the bottom MOSFET Drain, and the Phase B output.

Pin Description (Cont'd)

Pin 32: CAP_B

This pin is the positive supply of the high-side circuitry. The bootstrap capacitor for Phase B is connected between this pin and SB.

Pin 33: GB_A

This is the gate drive output for the bottom MOSFET in Phase A.

Pin 34: GT_A

This is the gate drive output for the top MOSFET in Phase A.

Pin 35: S_A

This pin is negative supply of the high-side drive circuitry. As such, it is the connection for the negative side of the bootstrap capacitor, the top MOSFET Source, the bottom MOSFET Drain, and the Phase A output.

Pin 36: CAP_A

This pin is the positive supply of the high-side circuitry. The bootstrap capacitor for Phase A is connected between this pin and SA.

Pin 42: V+

The supply voltage for the Si9979 is connected between this pin and ground. The internal logic and high-side supply voltages are derived from V+.

Pin 43: V_{DD}

V_{DD} is the internal logic and gate drive voltage. It is necessary to connect a capacitor between this pin and ground to insure that the current surges seen at the turn on of the bottom MOSFETs does not trip the undervoltage lockout circuitry.

Applications

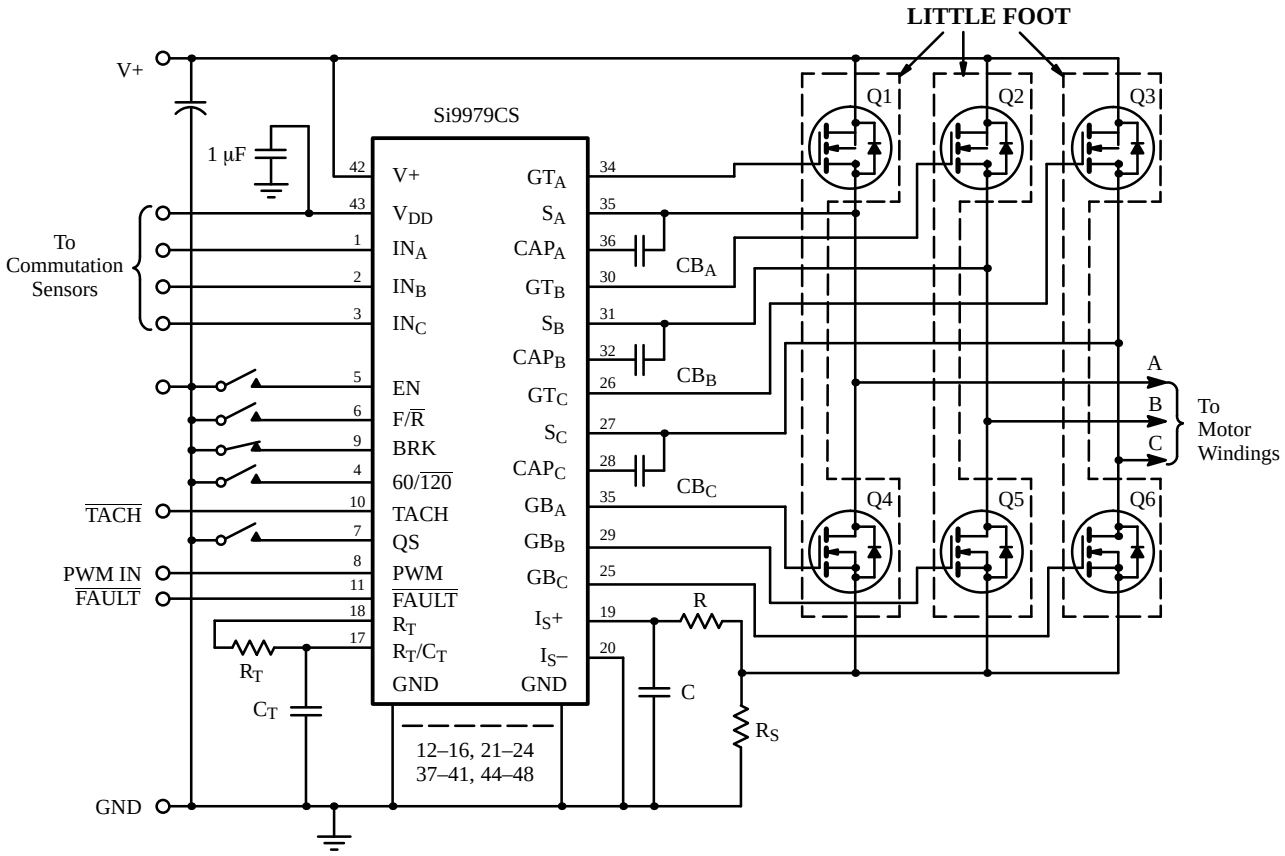


Figure 1. Three-Phase Brushless DC Motor Controller

Applications (Cont'd)

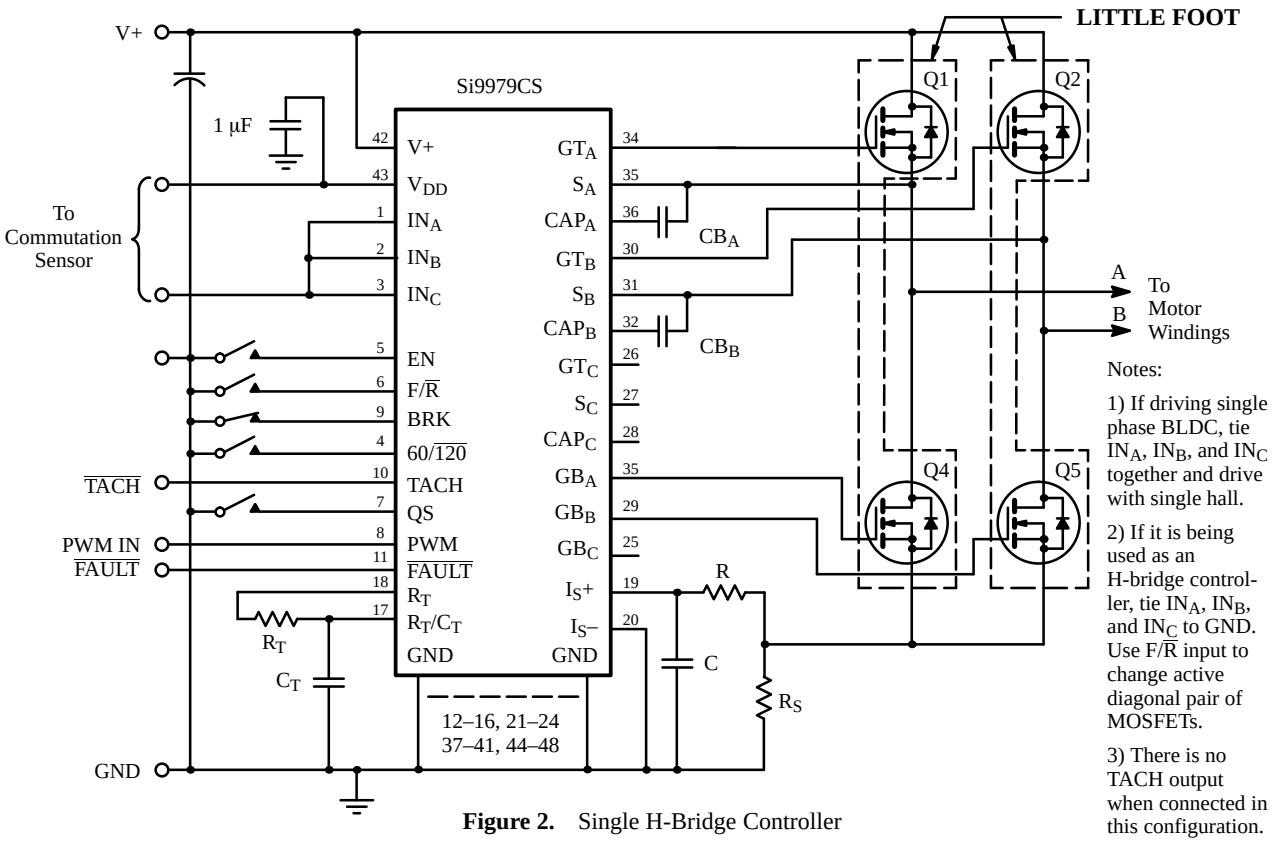


Figure 2. Single H-Bridge Controller

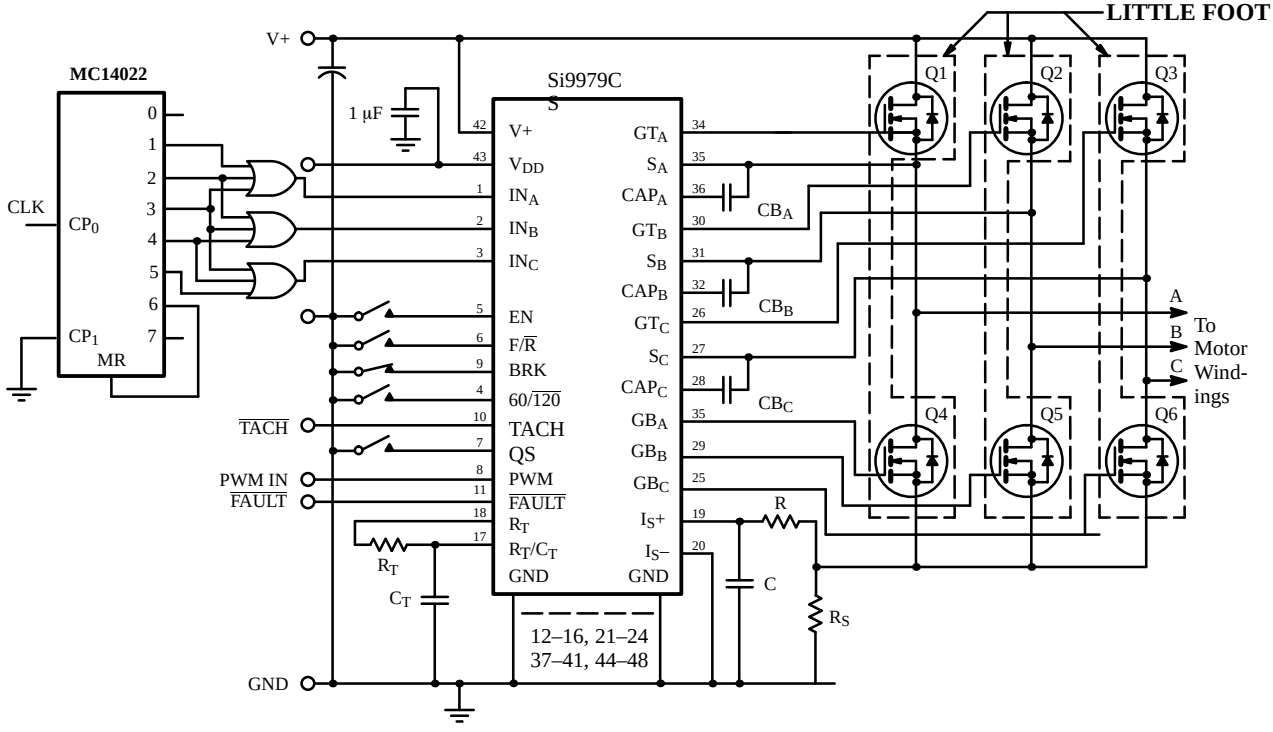


Figure 3. Three-Phase AC Motor Controller

Applications (Cont'd)

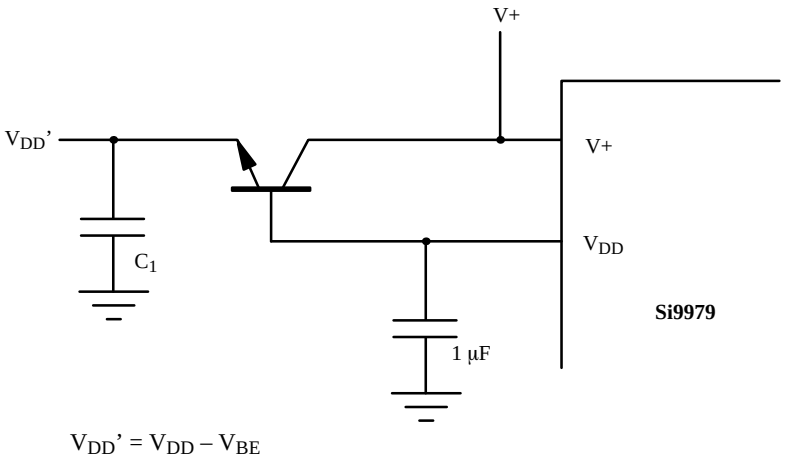


Figure 4. External V_{DD} Regulator