

Current-Sensing Low-Side MOSFET Driver

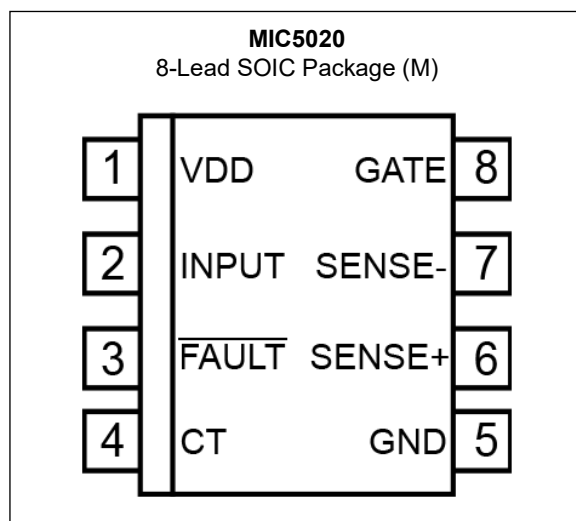
Features

- 11V to 50V operation
- 175 ns rise/fall time driving 2000 pF
- TTL compatible input with internal pull-down resistor
- Overcurrent limit
- Fault output indication
- Gate to source protection
- Compatible with current sensing MOSFETs

Applications

- Lamp control
- Heater control
- Motor control
- Solenoid switching
- Switch-mode power supplies
- Circuit breaker

Package Types



General Description

The MIC5020 low-side MOSFET driver is designed to operate at frequencies greater than 100 kHz (5kHz PWM for 2% to 100% duty cycle) and is an ideal choice for high-speed applications such as motor control, SMPS (switch mode power supplies), and applications using IGBTs.

The MIC5020 can also operate as a circuit breaker with or without automatic retry. The MIC5020's maximum supply voltage lends itself to control applications using up to 50V. The MIC5020 can control MOSFETs that switch voltages greater than 50V.

A rising or falling edge on the input results in a current source or sink pulse on the gate output. This output current pulse can turn on or off a 2000 pF MOSFET in approximately 175 ns. The MIC5020 then supplies a limited current (< 2 mA), if necessary, to maintain the output state. An overcurrent comparator with a trip voltage of 50 mV makes the MIC5020 ideal for use with a current sensing MOSFET.

An external low value resistor may be used instead of a sensing MOSFET for more precise overcurrent control. An optional external capacitor connected to the CT pin may be used to control the current shutdown duty cycle from 20% to < 1%.

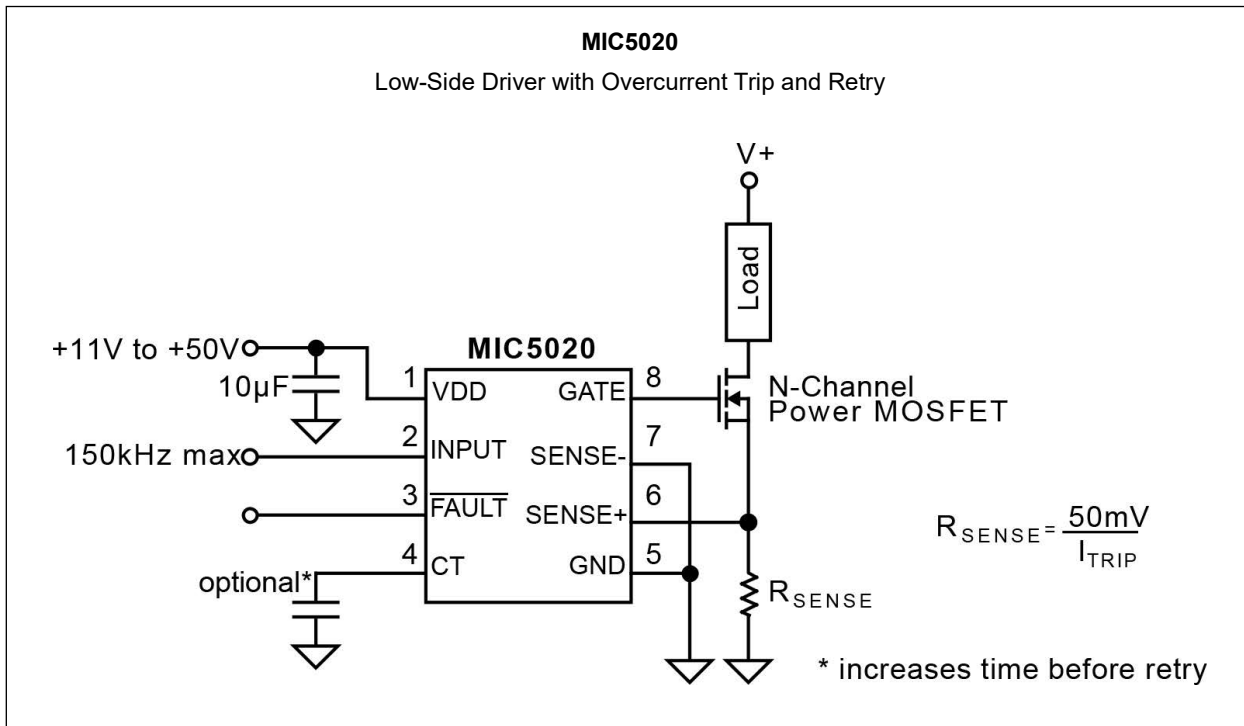
A duty cycle from 20% to about 75% is possible with an optional pull-up resistor from CT to VDD. An open collector output provides a fault indication when the sense inputs are tripped.

The MIC5020 is available in 8-lead SOIC package.

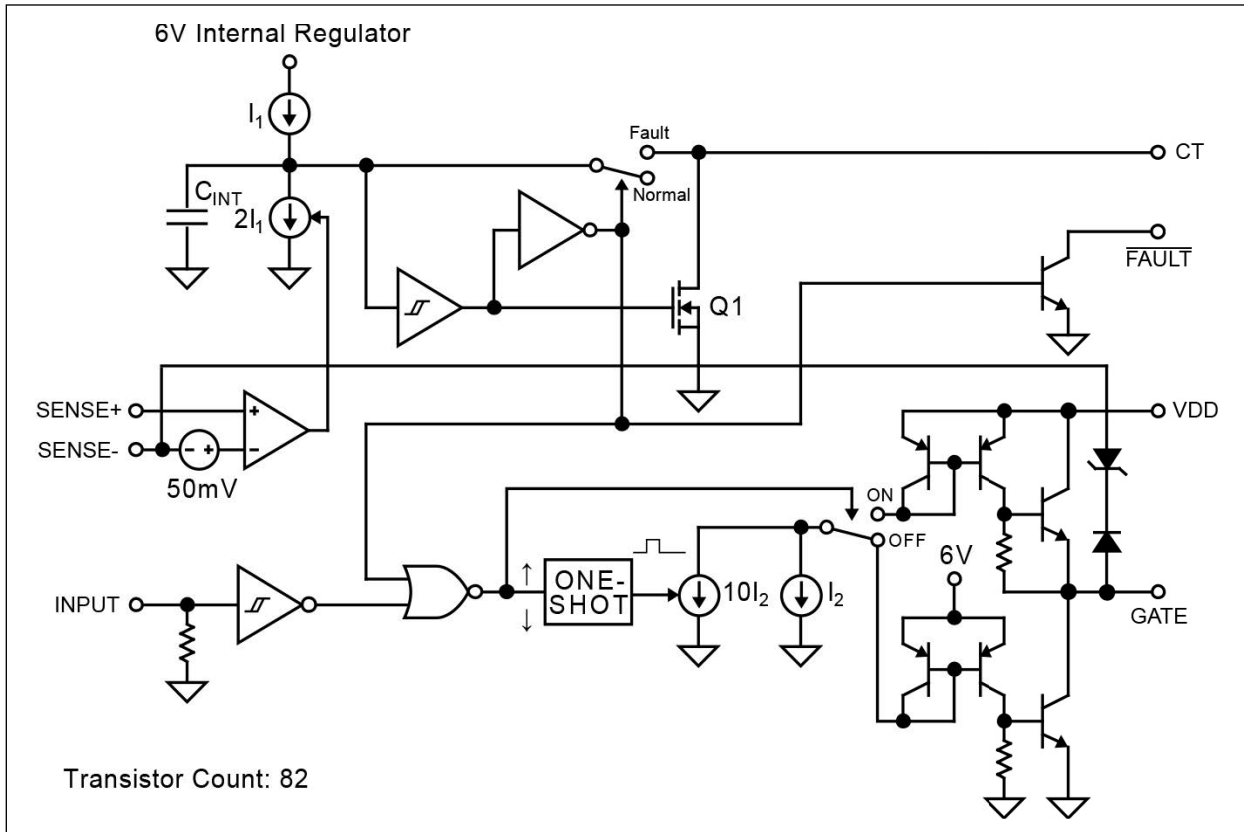
Other members of the MIC502x series include the MIC5021 high-side driver.

MIC5020

Typical Application Circuits



Functional Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Supply Voltage (V_{DD})	+55V
Input Voltage	-0.5V to +15V
Sense Differential Voltage	±6.5V
Sense+ or Sense- to GND	-0.5V to +50V
$\overline{\text{FAULT}}$ Voltage	+50V
Current into $\overline{\text{FAULT}}$	50 mA
Timer Voltage (C_T)	+5.5V

Operating Ratings ‡

Supply Voltage (V_{DD})	+11V to + 50V
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† **Notice:** Stresses above 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 those or any other conditions above those indicated in the operational sections of this specification is not intended. Exposure to maximum rating conditions for extended periods may affect device reliability.

‡ **Notice:** The device is not guaranteed to function outside its operating ratings.

ELECTRICAL CHARACTERISTICS (Note 1)

$T_A = 25^\circ\text{C}$, GND = 0V, $V_{DD} = 12\text{V}$, SENSE+/SENSE- = 0V, $\overline{\text{FAULT}}$ = Open, GATE CL = 1500 pF unless otherwise specified.						
Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
DC Supply Current	I_{VIN}	—	0.8	2	mA	$V_{DD} = 12\text{V}$, Input = 0V
		—	2	10	mA	$V_{DD} = 50\text{V}$, Input = 0V
		—	0.8	2	mA	$V_{DD} = 12\text{V}$, Input = 5V
		—	4	25	mA	$V_{DD} = 50\text{V}$, Input = 5V
Input Threshold	V_{IR}	0.8	1.4	2.0	V	—
Input Hysteresis	V_{IHYS}	—	0.1	—	V	—
Input Pull-Down Current	I_I	10	20	40	μA	Input = 5V
$\overline{\text{FAULT}}$ Output Saturation Voltage	V_{FSAT}	—	0.15	0.4	V	Fault Current = 1.6 mA (Note 1)
$\overline{\text{FAULT}}$ Output Leakage	I_F	-1	0.01	+1	μA	Fault = 50V
Current Limit Threshold	$I_{LIM TH}$	30	50	70	mV	Note 2
Gate On Voltage	V_G	10	11	—	V	$V_{DD} = 12\text{V}$
		14	15	18	V	$V_{DD} = 50\text{V}$

Note 1: Voltage remains low for time affected by C_T .

2: When using sense MOSFETs, it is recommended that $R_{SENSE} < 50\Omega$. Higher values may affect the sense MOSFET's current transfer ratio.

3: Input switched from 0.8V (TTL low) to 2.0V (TTL high), time for Gate transition from 0V to 2V.

4: Input switched from 0.8V (TTL low) to 2.0V (TTL high), time for Gate transition from 2V to 10V.

5: Input switched from 2.0V (TTL high) to 0.8V (TTL low), time for Gate transition from 11V (Gate ON voltage) to 10V.

6: Input switched from 2.0V (TTL high) to 0.8V (TTL low), time for Gate transition from 10V to 2V.

7: Frequency where gate on voltage reduces to 10V with 50% input duty cycle.

MIC5020

ELECTRICAL CHARACTERISTICS (CONTINUED)(Note 1)

$T_A = 25^\circ\text{C}$, GND = 0V, VDD = 12V, SENSE+/SENSE- = 0V, $\overline{\text{FAULT}}$ = Open, GATE CL = 1500 pF unless otherwise specified.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Gate On Time, Fixed	$t_{G(\text{ON})}$	2	5	10	μs	Sense Differential > 70 mV
Gate On Time, Adjustable	$t_{G(\text{OFF})}$	10	20	50	μs	Sense Differential > 70 mV, $C_T = 0$ pF
Gate Turn-on Delay	$t_{\text{DLH}(\text{ON})}$	—	400	800	ns	Note 3
Gate Rise Time	t_R	—	700	1500	ns	Note 4
Gate Turn-off Delay	$t_{\text{DLH}(\text{OFF})}$	—	900	1500	ns	Note 5
Gate Fall Time	t_F	—	500	1500	ns	Note 6
Maximum Operating Frequency	f_{MAX}	100	150	—	kHz	Note 7

Note 1: Voltage remains low for time affected by C_T .

2: When using sense MOSFETs, it is recommended that $R_{\text{SENSE}} < 50\Omega$. Higher values may affect the sense MOSFET's current transfer ratio.

3: Input switched from 0.8V (TTL low) to 2.0V (TTL high), time for Gate transition from 0V to 2V.

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6: Input switched from 2.0V (TTL high) to 0.8V (TTL low), time for Gate transition from 10V to 2V.

7: Frequency where gate on voltage reduces to 10V with 50% input duty cycle.

TEMPERATURE SPECIFICATIONS

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Operating Junction Temperature Range	T_J	-40	—	+85	$^\circ\text{C}$	—

2.0 TYPICAL PERFORMANCE CURVES

Note: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

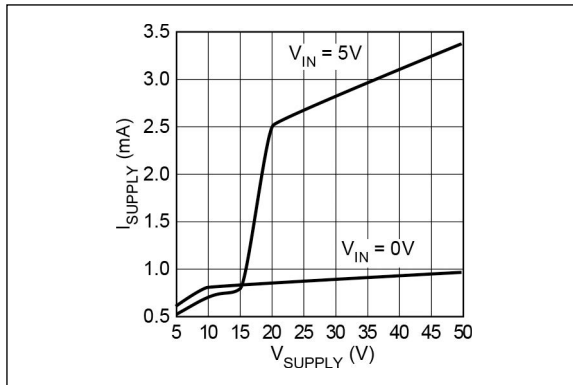


FIGURE 2-1: Supply Current vs. Supply Voltage.

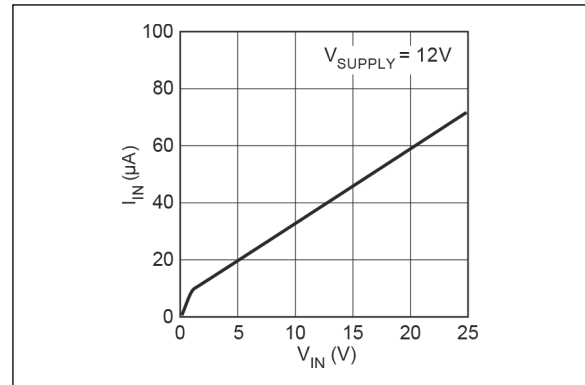


FIGURE 2-4: Input Current vs. Input Voltage.

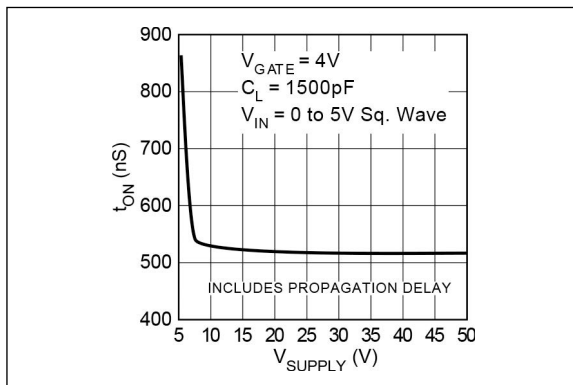


FIGURE 2-2: Turn-On Time vs. Supply Voltage.

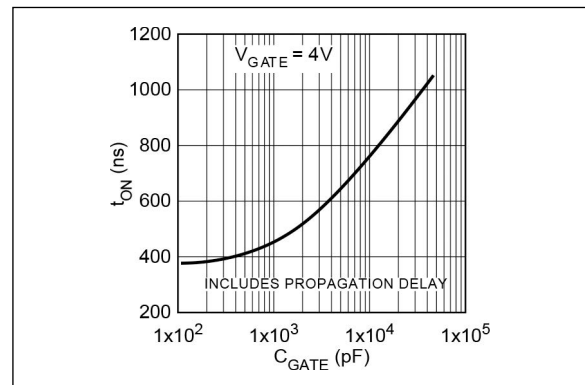


FIGURE 2-5: Turn-On Time vs. Gate Capacitance.

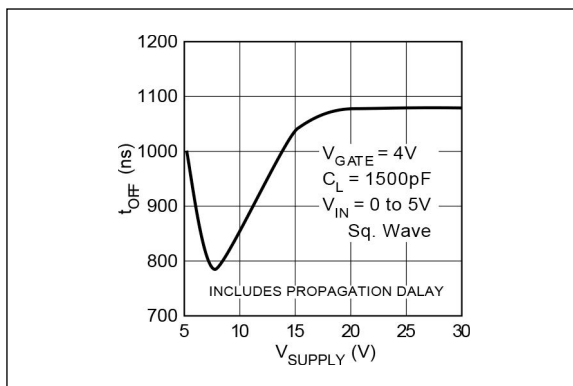


FIGURE 2-3: Turn-Off Time vs. Supply Voltage.

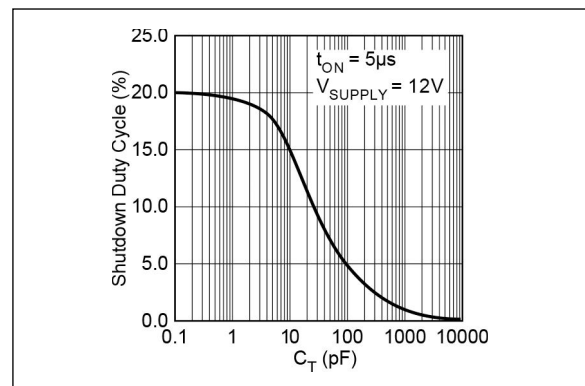


FIGURE 2-6: Overcurrent Shutdown Retry Duty Cycle.

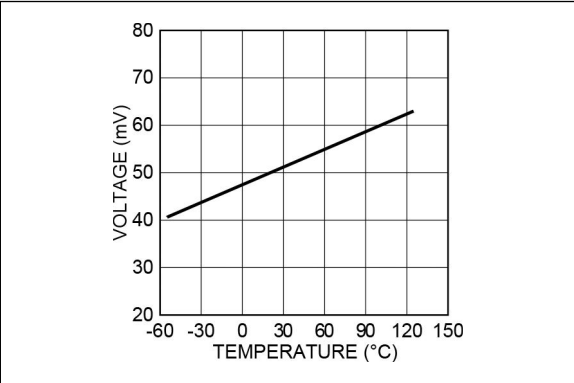


FIGURE 2-7: Sense Threshold vs. Temperature.

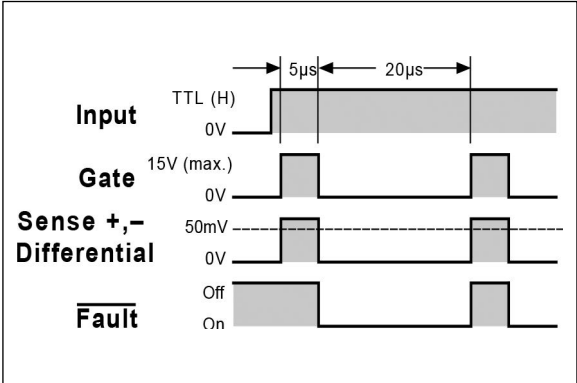


FIGURE 2-9: Timing Diagram - Fault Condition, CT = Open.

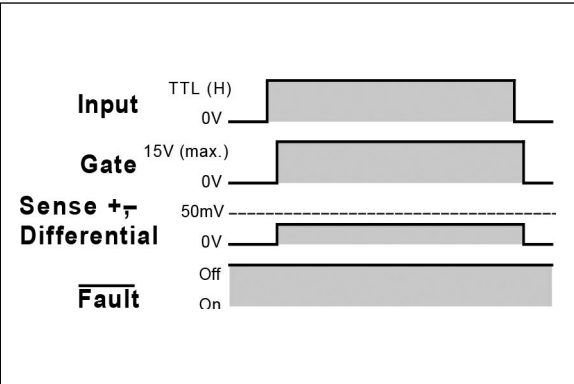


FIGURE 2-8: Timing Diagram - Normal Operation.

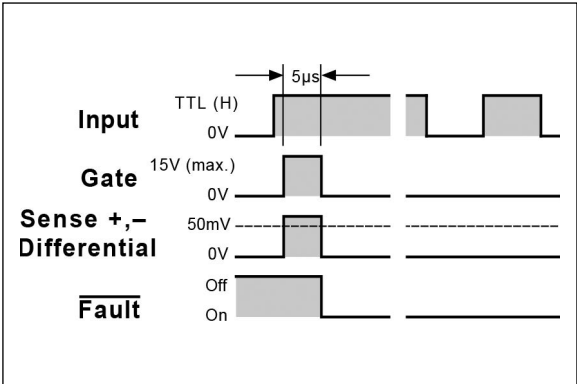


FIGURE 2-10: Timing Diagram - Fault Condition, CT = Grounded.

3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in [Table 3-1](#).

TABLE 3-1: PIN FUNCTION TABLE

Pin Number	Pin Name	Description
1	VDD	Supply: +11V to +50V. Decouple with $\geq 10 \mu\text{F}$ capacitor.
2	INPUT	TTL Compatible Input: Logic high turns the external MOSFET on. An internal pull-down returns an open pin to logic low.
3	$\overline{\text{FAULT}}$	Overcurrent Fault Indicator: When the sense voltage exceeds threshold, open collector output is open circuit for $5 \mu\text{s}$ ($t_{\text{G(ON)}}$), then pulled low for $t_{\text{G(OFF)}}$. $t_{\text{G(OFF)}}$ is adjustable from CT.
4	CT	Retry Timing Capacitor: Controls the off time ($t_{\text{G(OFF)}}$) of the overcurrent retry cycle. (Duty cycle adjustment.) • Open = 20% duty cycle. • Capacitor to Ground = approx. 20% to <1% duty cycle. • Pull-Up resistor = approx. 20% to approx. 75% duty cycle. • Ground = maintained shutdown upon overcurrent condition.
5	GND	Circuit Ground.
6	SENSE+	Current Sense Comparator (+) Input: Connect to high side of sense resistor or current sensing MOSFET sense lead. A built-in offset in conjunction with R_{SENSE} sets the load overcurrent trip point.
7	SENSE-	Current Sense Comparator (–) Input: Connect to the low side of the sense resistor (usually power ground).
8	GATE	Gate Drive: Drives the gate of an external power MOSFET. Also limits V_{GS} to 15V max. to prevent Gate to Source damage. Will sink and source current.

4.0 FUNCTIONAL DESCRIPTION

Refer to the [Functional Block Diagram](#).

4.1 Input

A signal greater than 1.4V (nominal) applied to the MIC5020 INPUT causes gate enhancement on an external MOSFET turning the external MOSFET on. An internal pull-down resistor insures that an open INPUT remains low, keeping the external MOSFET turned off.

4.2 GATE Output

Rapid rise and fall times on the GATE output are possible because each input state change triggers a one-shot which activates a high-value current sink ($10I_2$) for a short time. This draws a high current through a current mirror circuit, causing the output transistors to quickly charge or discharge the external MOSFET's gate.

A second current sink continuously draws the lower value of current used to maintain the gate voltage for the selected state. An internal 15V Zener diode protects the external MOSFET by limiting the gate output voltage when VDD is connected to higher voltages.

4.3 Overcurrent Limiting

Current source I_1 charges C_{INT} upon power up. An optional external capacitor connected to CT is discharged through MOSFET Q1. A fault condition (>50 mV from SENSE+ to SENSE-) causes the overcurrent comparator to enable current sink $2I_1$ which overcomes current source I_1 to discharge C_{INT} in a short time.

When C_{INT} is discharged, the INPUT is disabled, which turns off the GATE output; the FAULT output is enabled; and C_{INT} and CT are ready to be charged.

When the GATE output turns the MOSFET off, the overcurrent signal is removed from the sense inputs which deactivates current sink $2I_1$. This allows C_{INT} and the optional capacitor connected to CT to recharge. A Schmitt trigger delays the retry while the capacitor(s) recharge. Retry delay is increased by connecting a capacitor to CT (optional).

The retry cycle will continue until the fault is removed or the input is changed to TTL low. If CT is connected to ground, the circuit will not retry upon a fault condition.

4.4 Fault Output

The FAULT output is an open collector transistor. FAULT is active at approximately the same time the output is disabled by a fault condition (5 μ s after an overcurrent condition is sensed). The FAULT output is open circuit (off) during each successive retry (5 μ s).

5.0 APPLICATION INFORMATION

5.1 Supply Bypass

The MIC5020 MOSFET driver is intended for low-side switching applications where higher supply voltage, overcurrent sensing, and moderate speed are required.

5.2 Supply Voltage

A feature of the MIC5020 is that its supply voltage rating of up to 50V is higher than many other low-side drivers. The minimum supply voltage required to fully enhance an N-channel MOSFET is 11V. A lower supply voltage may be used with logic level MOSFETs. Approximately 6V is needed to provide 5V of gate enhancement.

5.3 Low-Side Switch Circuit Advantages

A moderate-speed low-side driver is generally much faster than a comparable high-side driver. The MIC5020 can provide the gate drive switching times and low propagation delay times that are necessary for high-frequency high-efficiency circuit operation in PWM (pulse width modulation) designs used for motor control, SMPS (switch mode power supply) and heating element control.

Switched loads (on/off) can benefit from the MIC5020's fast switching times by allowing use of MOSFETs with smaller safe operating areas. (Larger MOSFETs are often required when using slower drivers.)

5.4 Overcurrent Limiting

A 50 mV comparator is provided for current sensing. The low level trip point minimizes I^2R losses when power resistors are used for current sensing. Flexibility in choosing drain or source side sensing is provided by access to both SENSE+ and SENSE- comparator inputs.

The adjustable retry feature can be used to handle loads with high initial currents, such as lamps, motors, or heating elements and can be adjusted from the CT connection.

CT to ground causes maintained gate drive shutdown following overcurrent detection. CT open, or through a capacitor to ground, causes automatic retry. The default duty cycle (CT open) is approximately 20%. Refer to the electrical characteristics when selecting a capacitor for a reduced duty cycle.

CT through a pull-up resistor to VDD increases the duty cycle. *Increasing the duty cycle increases the power dissipation in the load and MOSFET.* Circuits may become unstable at a duty cycles of about 75% or higher, depending on the conditions. **Caution:** The MIC5020 may be damaged if the voltage on CT exceeds the absolute maximum rating.

An overcurrent condition is externally signaled by an open collector (FAULT) output. The MIC5020 may be used without current sensing by connecting SENSE+ and SENSE- to ground.

5.5 Current Sense Resistors

Lead length can be significant when using low value ($< 1\Omega$) resistors for current sensing. Errors caused by lead length can be avoided by using four-terminal current sensing resistors. Four-terminal resistors are available from several manufacturers.

5.6 Lamp Driver Application

Incandescent lamps have a high inrush current (low resistance) when turned on. The MIC5020 can perform a "soft start" by pulsing the MOSFET (overcurrent condition) until the filament is warm enough for its current to decrease (resistance increases). The sense resistor is selected so the voltage across the sense resistor drops below the sense threshold (50 mV) as the filament becomes warm. The MOSFET is no longer pulsed to limit current and the lamp turns completely on.

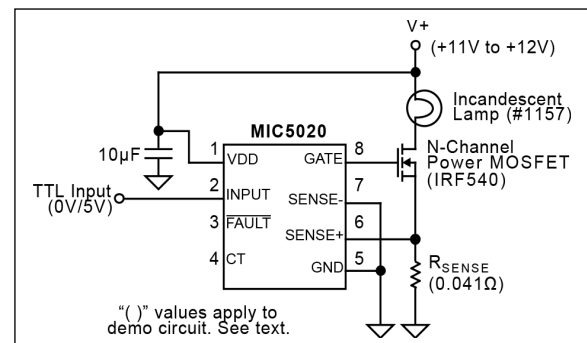


FIGURE 5-1: Lamp Driver with Current Sensing.

A lamp may not fully turn on if the filament does not heat up adequately. Changing the duty cycle, sense resistor, or both to match the filament characteristics can correct the problem.

Soft start can be demonstrated using a #1157 dual-filament automotive lamp. The value of R_S shown in Figure 5-1 allows for soft start of the higher-resistance filament (measures approximately 2.1Ω cold or 21Ω hot).

5.7 Solenoid Driver Application

The MIC5020 can be directly powered by the control voltage supply in typical 11 Vdc through 50 Vdc control applications. Current sensing has been omitted as an example.

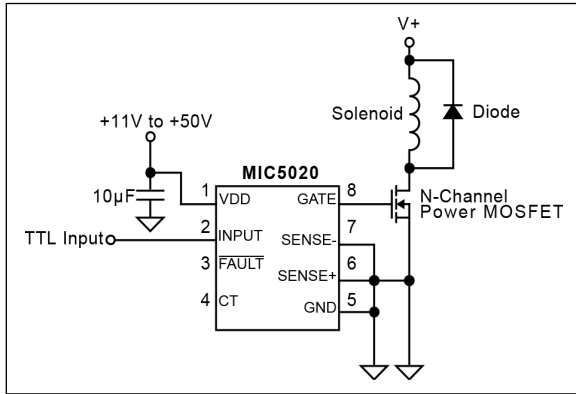


FIGURE 5-2: Solenoid Driver, without Current Sensing.

A diode across the load protects the MOSFET from the voltage spike generated by the inductive load upon MOSFET turn off. The peak forward current rating of the diode should be greater than the load current.

5.8 Current Sensing MOSFET Application

A current sensing MOSFET allows current sensing without adding additional resistance to the power switching circuit.

A current sensing MOSFET has two source connections: a “power source” for power switching and a “current source” for current sensing. The current from the current source is approximately proportional to the current through the power source, but much smaller. A current sensing ratio (I_{SOURCE}/I_{SENSE}) is provided by the MOSFET manufacturer.

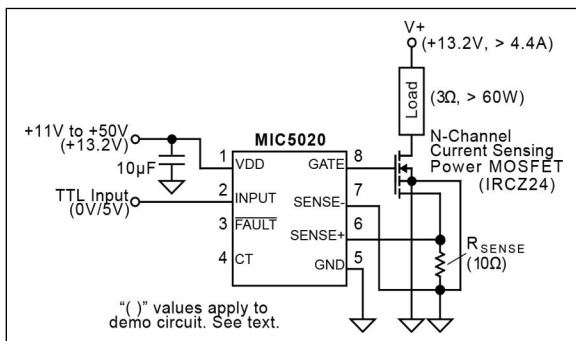


FIGURE 5-3: Using a Current Sensing MOSFET.

The MOSFET current source is used to develop a voltage across a sense resistor. This voltage is monitored by the MIC5020 (SENSE+ and SENSE– pins) to identify an overcurrent condition.

The value of the sense resistor can be estimated with:

EQUATION 5-1:

$$R_{SENSE} = \frac{(rV_{TRIP}R_{DS(ON)})}{(I_{LOAD}R_{DS(ON)} - V_{TRIP})}$$

R_{SENSE}	= external “sense” resistor
V_{TRIP}	= 50 mV (0.050V) for MIC5020
r	= manufacturer’s current sense ratio: (I_{SOURCE}/I_{SENSE})
$R_{DS(ON)}$	= manufacturer’s power source on resistance
I_{LOAD}	= load current (power source current)

The drain to source voltage under different fault conditions affects the behavior of the MOSFET current source; that is, the current source will respond differently to a slight over-current condition ($V_{DS(ON)}$ is very small) than to a short circuit (where $V_{DS(ON)}$ is approximately equal to the supply voltage).

Adjustment of the sense resistor value by experiment starting from the above formula will provide the quickest selection of R_{SENSE} . Refer to manufacturer’s data sheets and application notes for detailed information on current sensing MOSFET characteristics.

Figure 5-3 includes values which can be used to demonstrate circuit operation. The IRCZ24 MOSFET has a typical sense ratio of 780 and a $R_{DS(ON)}$ of 0.10Ω. A large 3Ω wirewound load resistor will cause inductive spikes which should be suppressed using a diode (using the same configuration as Figure 5-2).

5.9 Faster MOSFET Switching

The MIC5020’s GATE current can be multiplied using a pair of bipolar transistors to permit faster charging and discharging of the external MOSFET’s gate.

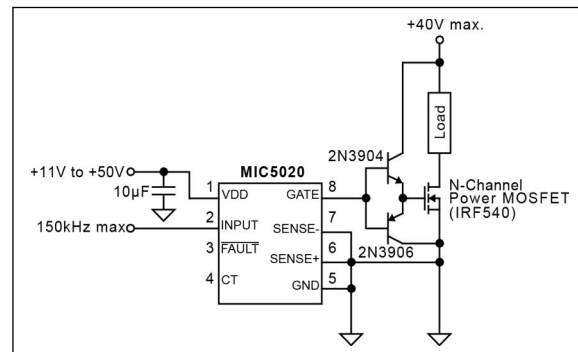


FIGURE 5-4: Faster MOSFET Switching Circuit.

NPN and PNP transistors are used to respectively charge and discharge the MOSFET gate. The MIC5020 gate current is multiplied by the transistor β .

The switched circuit voltage can be increased above 40V by selecting transistors with higher ratings.

5.10 Remote Overcurrent Limiting Reset

In circuit breaker applications where the MIC5020 maintains an off condition after an overcurrent condition is sensed, the CT pin can be used to reset the MIC5020.

Switching Q1 on pulls CT low, which keeps the MIC5020 GATE output off when an overcurrent is sensed. Switching Q1 off causes CT to appear open. The MIC5020 retries in about 20 μ s and continues to retry until the overcurrent condition is removed.

For test purposes, a 680 Ω load resistor and 3 Ω sense resistor will produce an overcurrent condition when the load's supply (V+) is approximately 12V or greater.

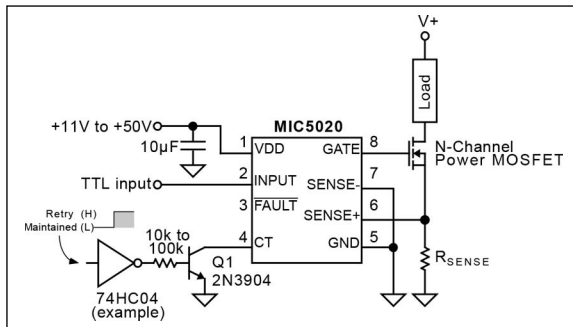


FIGURE 5-5: Remote Control Circuit.

6.0 PACKAGING INFORMATION

6.1 Package Marking Information

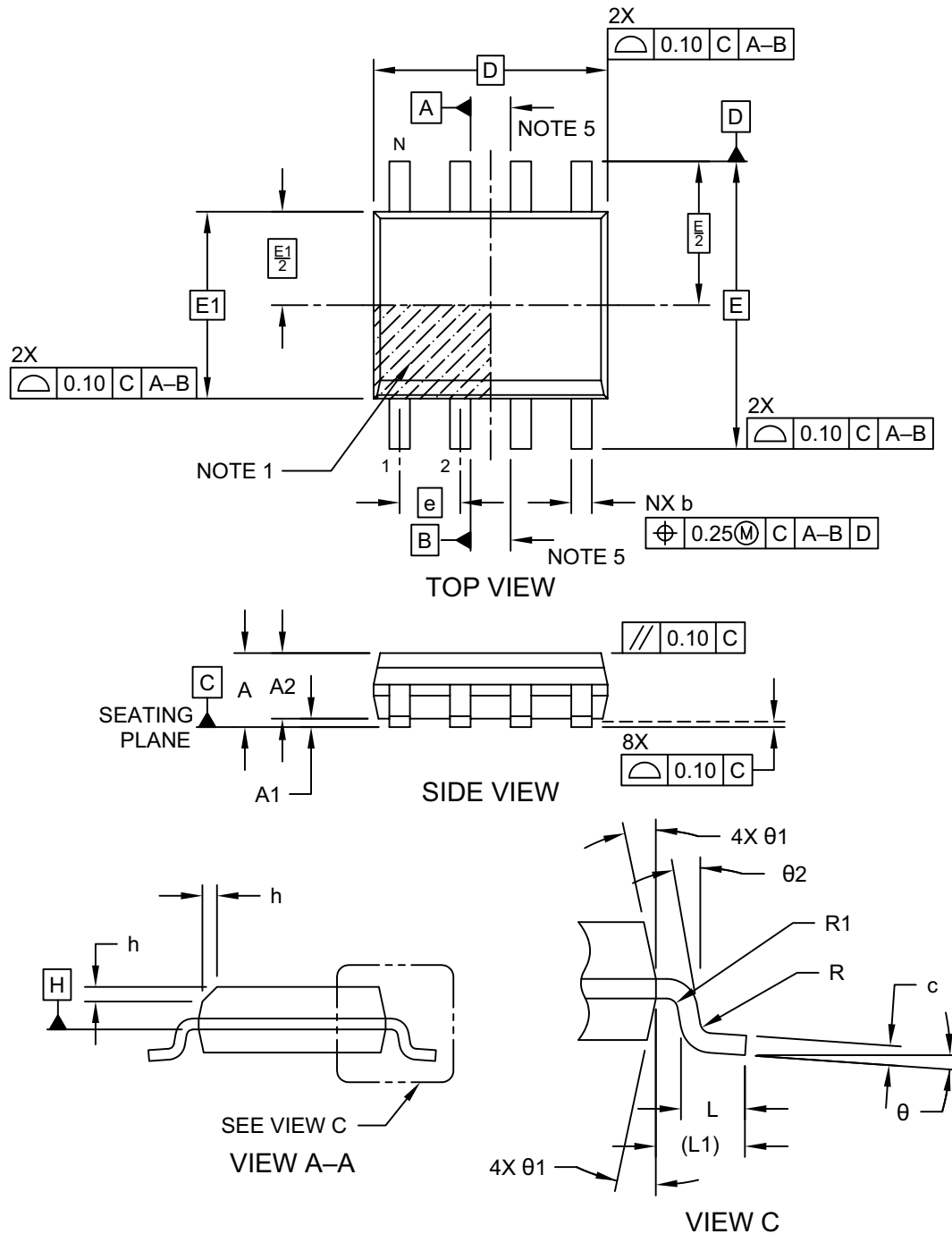


PACKAGE MARKING DRAWING SYMBOLS LEGEND

Symbol	Definition
XX . . . X	Product code or customer-specific information. (Note 1, Note 2)
YYWW	Date code, where YY is the last 2 digits of calendar year and WW is the work week (i.e., week of January 1 is week 01). (Note 3)
M	Month of assembly (if applicable). January is represented by “A” and each month thereafter follows the order of the alphabet through “L” for December.
NNN	Alphanumeric traceability code. (Note 3, Note 4)
	Pb-free JEDEC designator for Matte Tin (Sn).
*	Indicates this package is Pb-free. The Pb-free JEDEC designator (the symbol in the row above this one) can be found on the outer packaging for this package.
	Pin one index is identified by a dot, delta up, or delta down (triangle mark).
Note 1: If the full Microchip part number cannot fit on one line, it will be carried over to the next line, limiting the number of available characters for customer-specific information. The package may or may not include the corporate logo. 2: Any underbar (_) and/or overbar (¯) symbols shown in a package marking drawing may not be to scale. 3: If the full date code (YYWW) and the alphanumeric traceability code (NNN)—usually marked together on the last or only line of a package marking as the seven-character YYWWNNN—cannot fit on the package together, the codes will be truncated based on the number of available character spaces, as follows: 6 characters = YWWNNN; 5 characters = WWNNN; 4 characters = WNNN; 3 characters = NNN; 2 characters = NN; 1 character = N. 4: Some products might have a “Y” symbol at the end of the last or only line in a package marking, usually at the end of the alphanumeric traceability code (NNN or truncated versions), to indicate the product is Pb-free.	

8-Lead 3.9 mm SOIC [3BX] Package Outline and Recommended Land Pattern

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>

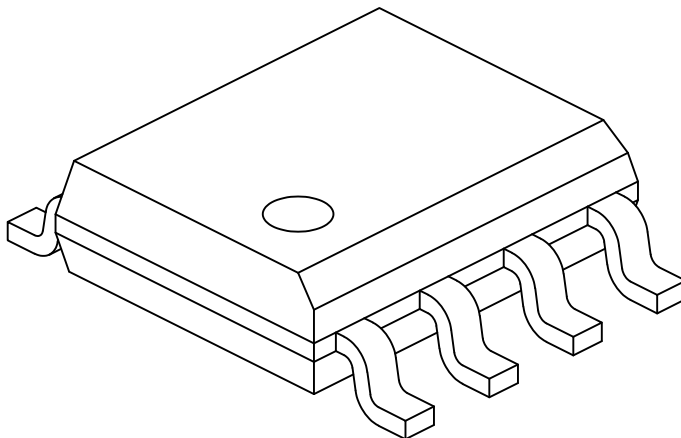


Microchip Technology Drawing No. C04-057-3BX Rev K Sheet 1 of 2

MIC5020

8-Lead 3.9 mm SOIC [3BX] Package Outline and Recommended Land Pattern

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Pins	N	8		
Pitch	e	1.27 BSC		
Overall Height	A	–	–	1.75
Molded Package Thickness	A2	1.25	–	–
Standoff §	A1	0.10	–	0.25
Overall Width	E	6.00 BSC		
Molded Package Width	E1	3.90 BSC		
Overall Length	D	4.90 BSC		
Chamfer (Optional)	h	0.25	–	0.50
Foot Length	L	0.40	–	1.27
Footprint	L1	1.04 REF		
Lead Thickness	c	0.17	–	0.25
Lead Width	b	0.31	–	0.51
Lead Bend Radius	R	0.07	–	–
Lead Bend Radius	R1	0.07	–	–
Foot Angle	θ	0°	–	8°
Mold Draft Angle	θ1	5°	–	15°
Lead Angle	θ2	0°	–	–

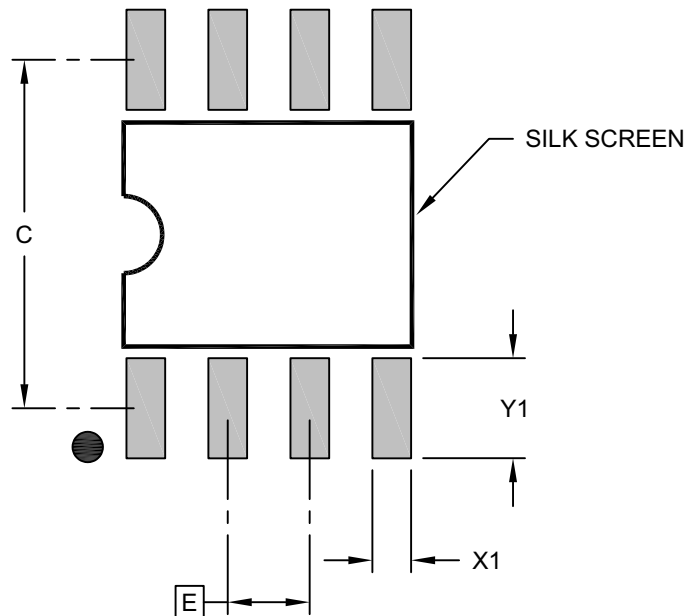
Notes:

- Pin 1 visual index feature may vary, but must be located within the hatched area.
- § Significant Characteristic
- Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm per side.
- Dimensioning and tolerancing per ASME Y14.5M
BSC: Basic Dimension. Theoretically exact value shown without tolerances.
REF: Reference Dimension, usually without tolerance, for information purposes only.
- Datums A & B to be determined at Datum H.

Microchip Technology Drawing No. C04-057-3BX Rev K Sheet 2 of 2

8-Lead 3.9 mm SOIC [3BX] Package Outline and Recommended Land Pattern

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E	1.27 BSC		
Contact Pad Spacing	C		5.40	
Contact Pad Width (X8)	X1			0.60
Contact Pad Length (X8)	Y1			1.55

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-2057-3BX Rev K

MIC5020

NOTES:

APPENDIX A: REVISION HISTORY

Revision A (January 2025)

- Converted Micrel document MIC5020 to Microchip data sheet DS20006964A.
- Minor text changes throughout.

MIC5020

NOTES:

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, contact your local Microchip representative or sales office.

PART No.	X	X	-XX	Examples:
Device	Junction Temp. Range	Package Type	Media Type	
Device:	MIC5020	=	Current-Sensing Low-Side MOSFET Driver	a) MIC5020YM: MIC5020, -40°C to +85°C Junction Temp. Range, 8-Lead SOIC, 95/Tube
Junction Temperature Range:	Y	=	-40°C to +85°C	b) MIC5020YM-TR: MIC5020, -40°C to +85°C Junction Temp. Range, 8-Lead SOIC, 2500/Reel
Package:	M	=	8-Lead SOIC	
Media Type:	<blank>	=	95/Tube	
	-TR	=	2500/Reel	
				Note1: Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package. Check with your Microchip Sales Office for package availability with the Tape and Reel option.

MIC5020

NOTES:

Microchip Information

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