## 20V to 250V Driver for High Power PIN Diode Switches

Rev. V1

## Features

- 20 V to 250 V Back Bias in Off State
- 200 mA Series Diode Bias Current at $+25^{\circ} \mathrm{C}$
- 50 mA Shunt Diode Bias Current at $+25^{\circ} \mathrm{C}$
- Propagation Delay less than $8 \mu \mathrm{~s}$
- Low Quiescent Current Consumption
- 3 V or 5 V CMOS Logic Control
- 7 mm QFN-16LD Package
- Tape and Reel Packaging Available
- RoHS* Compliant and $260^{\circ} \mathrm{C}$ Reflow Compatible


## Description

The MADR-010574 switch driver is designed to work with M/A-COM Technology Solutions high power and high voltage PIN diodes. This driver consists of two independently controlled drivers which are able to provide 200 mA series / 50 mA shunt current to a series/shunt, series/shunt SPDT PIN diode switch. The back bias voltage is configurable from 20 V to 250 V . High voltage level shifters are integrated so that it can be easily controlled by 3 V or 5 V CMOS logic. While consuming low quiescent current, this driver has a typical delay of less than $8 \mu \mathrm{~s}$ when driving 220 pF capacitor load. If needed, the switching speed can be improved by consuming more quiescent power.

This driver is packaged in a lead free 7 mm PQFN16LD package and is available in tape and reel packaging for high volume applications.

## Ordering Information

| Part Number | Package |
| :---: | :---: |
| MADR-010574-000100 | Bulk Packaging |
| MADR-010574-0001TR | 1000 piece Reel |
| MADR-010574-001SMB |  <br> MA4P504-1072T Diodes |

## Functional Schematic



## Pin Configuration ${ }^{1}$

| Pin No. | Pin Name | Description |
| :---: | :---: | :---: |
| 1 | SH1 | Shunt1 |
| 2 | C1 | Control Logic 1 |
| 3 | I BIAS | Bias Voltage |
| 4 | SER1 | Series1 |
| 5 | N/C $^{2}$ | No Connection |
| 6 | GND | Ground |
| 7 | GND | Ground |
| 8 | N/C | No Connection |
| 9 | SH2 | Shunt2 |
| 10 | V $_{\text {CC }}$ | Control Voltage |
| 11 | C2 | Control Logic 2 |
| 12 | SER2 | Series2 |
| 13 | GND | Ground |
| 14 | N/C ${ }^{2}$ | No Connection |
| 15 | N/C ${ }^{2}$ | No Connection |
| 16 | VDD $^{17}$ | Paddle |
| 17 | Drain Voltage |  |

1. The paddle of the QFN package should be tied to ground.
2. N/C pins (except Pin 15) can be grounded. The clearance from high voltage pins should be at least 0.8 mm . Pin 15 must be left open.
[^0]
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Recommended Operating Conditions

| Parameter | Test Conditions | Unit | Min. | Typ. | Max. |
| :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathrm{V}_{\mathrm{cc}}$ | Nominal $\mathrm{V}_{\mathrm{Cc}}=3.3 \mathrm{~V}$ <br> Nominal $\mathrm{V}_{\mathrm{CC}}=5.0 \mathrm{~V}$ | V | $\begin{aligned} & 3.0 \\ & 4.5 \end{aligned}$ | $\begin{aligned} & 3.3 \\ & 5.0 \end{aligned}$ | $\begin{aligned} & 3.6 \\ & 5.5 \end{aligned}$ |
| $V_{D D}$ | - | V | 20 | - | 250 |
| Control1, Control2 ${ }^{3}$ | Logic "0" <br> Logic "1" | V | $\begin{gathered} 0.0 \\ 0.7 \times \mathrm{V}_{\mathrm{CC}} \end{gathered}$ | $\begin{aligned} & 0.0 \\ & \mathrm{~V}_{\mathrm{cc}} \end{aligned}$ | $\begin{gathered} 0.3 \times V_{\mathrm{CC}} \\ V_{\mathrm{CC}} \end{gathered}$ |
| Series1/Series2 Sinking Current ${ }^{4}$ | $\begin{aligned} & -40^{\circ} \mathrm{C} \\ & +25^{\circ} \mathrm{C} \\ & +85^{\circ} \mathrm{C} \end{aligned}$ | mA | - | - | $\begin{aligned} & 300 \\ & 200 \\ & 150 \end{aligned}$ |
| Shunt1/Shunt2 Sinking Current ${ }^{4}$ | $\begin{aligned} & -40^{\circ} \mathrm{C} \\ & +25^{\circ} \mathrm{C} \\ & +85^{\circ} \mathrm{C} \end{aligned}$ | mA | - | - | $\begin{aligned} & 65 \\ & 55 \\ & 50 \end{aligned}$ |
| $\mathrm{I}_{\text {BIAS }}{ }^{5,6}$ | $+25^{\circ} \mathrm{C}$ | $\mu \mathrm{A}$ | 2 | 6 | 150 |
| Operating Temperature | - | ${ }^{\circ} \mathrm{C}$ | -40 | +25 | +85 |

3. Unused Controls should be either grounded or connected to $V_{c c}$. They should never be left open.
4. Refer to "Application Circuit: Driving SPDT Switch with MA4P504-1072T Pin Diodes" for configuration of diode bias currents.
5. This sinking bias current is necessary for normal driver operation. The easiest way is to connect a 0402 resistor $R_{\text {BIAS }}$ between Pin $V_{C C}$ and Pin $I_{\text {BIAS. }}$ Then $I_{\text {BIAS }}$ can be calculated by: $\mathrm{I}_{\text {BIAS }}=\left(\mathrm{V}_{\mathrm{CC}}-0.6\right) /\left(500+\mathrm{R}_{\mathrm{BIAS}}\right)$
6. Refer to graph "Typ. Ton Driving 220 pF Caps vs. IBIAS" on page 3 and the chart "Typ. IDD vs. IBIAS at $25^{\circ} \mathrm{C}$ " on page 4 for the tradeoff between switching speed and power consumption.

## Absolute Maximum Ratings ${ }^{7,8}$

| Parameter | Absolute Maximum |
| :---: | :---: |
| $\mathrm{V}_{\mathrm{CC}}$ | -0.5 V to +7 V |
| $V_{D D}$ | -0.5 V to 275 V |
| C1, C2 (Logic) | -0.5 V to 7 V |
| Series1/Series2 Sinking Current $\begin{aligned} & -40^{\circ} \mathrm{C} \\ & +25^{\circ} \mathrm{C} \\ & +85^{\circ} \mathrm{C} \end{aligned}$ | 550 mA 450 mA 350 mA |
| $\begin{gathered} \text { Shunt1/Shunt2 Sinking Current } \\ -40^{\circ} \mathrm{C} \\ +25^{\circ} \mathrm{C} \\ +85^{\circ} \mathrm{C} \end{gathered}$ | 150 mA 150 mA 100 mA |
| Series/Shunt Outputs Sourcing Current | 25 mA |
| $\mathrm{I}_{\text {BIAS }}$ | $500 \mu \mathrm{~A}$ |
| ESD HBM Rating | $>1 \mathrm{kV}$ |
| Operating Temperature | -40 to $+125^{\circ} \mathrm{C}$ |
| Storage Temperature | -55 to $+150^{\circ} \mathrm{C}$ |

7. M/A-COM Technology Solutions does not recommend sustained operation near these survivability limits.
8. Exceeding any one or combination of these limits may cause permanent damage to this device.

Truth Table ${ }^{9}$

| C1 | C2 | Series1 | Shunt1 | Series2 | Shunt2 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 0 | 0 | Low | High | Low | High |
| 0 | 1 | Low | High | High | Low |
| 1 | 0 | High | Low | Low | High |
| 1 | 1 | High | Low | High | Low |

9. The actual voltage levels for "Low" and "High" are dependent on the current load to the driver. They can be estimated from the driver on resistance.

## Powering On/Off Sequence:

$V_{D D}$ should be turned on after $V_{C C}$, and the rise time of $V_{D D}$ should be slower than $2.5 \mu \mathrm{~s}$. When powering off, $\mathrm{V}_{\mathrm{DD}}$ should be turned off before $\mathrm{V}_{\mathrm{CC}}$.

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Electrical Specifications: $\mathrm{T}_{\mathrm{A}}=+25^{\circ} \mathrm{C}, \mathrm{V}_{\mathrm{CC}}=3.3 \mathrm{~V}, \mathrm{~V}_{\mathrm{DD}}=250 \mathrm{~V}, \mathrm{I}_{\mathrm{BIAS}}=6 \mu \mathrm{~A}^{10}$

| Parameter | Test Conditions | Unit | Min. | Typ. | Max. |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Quiescent Supply Currents | $\begin{aligned} & V_{\mathrm{CC}}(3.3 \mathrm{~V})^{11} \\ & \mathrm{~V}_{\mathrm{DD}}(250 \mathrm{~V}) \end{aligned}$ | $\mu \mathrm{A}$ | - | $\begin{gathered} 6 \\ 25 \end{gathered}$ | $\begin{aligned} & 10 \\ & 37 \end{aligned}$ |
| Control Input Leakage Current | - | $\mu \mathrm{A}$ | - | - | 1 |
| Series Pull-down FET On Resistance | 200 mA Load | $\Omega$ | - | 9 | 11.4 |
| Shunt Pull-down FET On Resistance | 50 mA Load | $\Omega$ | - | 26 | 30 |
| Switching Speed Driving 220pF Caps: Series ${ }^{12}$ <br> Ton <br> Toff <br> Tr <br> Tf | 50\% CTL to 95\% Voltage 50\% CTL to 5\% Voltage 10\% - $90 \%$ 90\% - 10\% | $\mu \mathrm{s}$ | - | $\begin{gathered} 6.2 \\ 0.22 \\ 5.1 \\ 0.1 \end{gathered}$ | - |
| Switching Speed Driving 220pF Caps: Shunt ${ }^{12}$ $\mathrm{~T}_{\text {ON }}$ $\mathrm{T}_{\text {OFF }}$ Tr Tf | 50\% CTL to 95\% Voltage $50 \%$ CTL to 5\% Voltage 10\% - $90 \%$ 90\% - 10\% | $\mu \mathrm{s}$ | - | $\begin{gathered} 3.1 \\ 0.2 \\ 2.6 \\ 0.08 \end{gathered}$ | - |

10. The parameters were measured with $500 \mathrm{k} \Omega \mathrm{R}_{\text {BIAS }}$ connecting between pin $\mathrm{V}_{C C}$ and pin $\mathrm{I}_{\text {BIAS }}$.
11. $I_{B A S}$ is included in the quiescent $\mathrm{V}_{\mathrm{CC}}$ current due to the bias configuration.
12. Switching parameters were measured driving 220 pF capacitors with no current load. Controls C 1 and C 2 were tied together. It will be faster when C 2 is inverted from C1, which is case driving a SPDT switch.

Typ. Ton Driving 220pF Caps vs VDD

$$
\text { VCC }=3.3 \mathrm{~V} \text {, IBIAS }=6 \mu \mathrm{~A}, 25^{\circ} \mathrm{C}
$$



Typ. Ton Driving 220pF Caps vs IbIAs $V C C=3.3 \mathrm{~V}, \mathrm{VDD}=250 \mathrm{~V}, 25^{\circ} \mathrm{C}$


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## 20V to 250V Driver for High Power PIN Diode Switches

## Performance Driving M/A-COM MA4P504-1072T PIN Diode SPDT Switch ${ }^{13}$



Typ. Ton (50\% Ctl to 90\% RF) vs. VDD
$\mathrm{VCC}=3.3 \mathrm{~V}, \mathrm{IBIAS}=6 \mu \mathrm{~A}$
Iseries $=200 \mathrm{~mA}$, Ishunt $=50 \mathrm{~mA}$


Typ. IDD vs IbIAs at $25^{\circ} \mathrm{C}$


Typ. Toff (50\% Ctl to 10\% RF)
VDD $=250 \mathrm{~V}, \mathrm{VCC}=3.3 \mathrm{~V}$, IBIAS $=6 \mu \mathrm{~A}$


- Iseries $=50 \mathrm{~mA}$,Ishunt $=10 \mathrm{~mA}$


Typ. Toff ( $50 \% \mathrm{CtI}$ to $10 \% \mathrm{RF}$ ) vs. VDD
$\mathrm{VCC}=3.3 \mathrm{~V}$, IBIAS $=6 \mu \mathrm{~A}$
Iseries $=200 \mathrm{~mA}$, Ishunt $=50 \mathrm{~mA}$

13. The switch is a series/shunt, series/shunt SPDT switch using four M/A-COM MA4P504-1072T PIN diodes. Schematic is on next page. Switching parameters were measured with 500 MHz 20W CW RF signal.

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## Application Circuit: Driving SPDT Switch with MA4P504-1072T PIN Diodes ${ }^{14}$


14. This is the schematic of MADR-010547-001SMB. The frequency range for this application circuit is 200 MHz to 500 MHz . The bias current for the series diodes is 200 mA . The bias current for the shunt diodes is 50 mA . The recommended inductors are Coil Craft 0603LS-181XJLB for both current and frequency considerations. For different frequency applications, both capacitors and inductors should be adjusted accordingly.

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## 20V to 250V Driver for High Power PIN Diode Switches

## Recommended PCB



## Parts List

| Part | Value | Size |
| :---: | :---: | :---: |
| C5 | $0.01 \mu \mathrm{~F}, 500 \mathrm{~V}$ | 0805 |
| C6 - C12 | $100 \mathrm{pF}, 500 \mathrm{~V}$ | 0805 |
| C13 - C15 | $0.1 \mu \mathrm{~F}, 16 \mathrm{~V}$ | 0402 |
| L1 - L8 | 180 nH | 0603 |
| R1 | $1.5 \Omega, 1 \mathrm{~W}$ | 2512 |
| R2 | $15 \Omega, 0.5 \mathrm{~W}$ | 1206 |
| R3 | $499 \mathrm{~K} \Omega, 1 / 16 \mathrm{~W}$ | 0402 |
| D1 - D4 | MA4P504-1072 |  |

Footprint


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## Lead Free 7mm PQFN-16LD ${ }^{\dagger}$


${ }^{\dagger}$ This is not a JEDEC standard package. Please refer to Application Note for footprint and lead-free solder reflow recommendations.

## Handling Procedures

Please observe the following precautions to avoid damage:

## Static Sensitivity

Silicon Circuits are sensitive to electrostatic discharge (ESD) and can be damaged by static electricity. Proper ESD control techniques should be used when handling these devices.

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Офис по работе с юридическими лицами:
105318, г.Москва, ул.Щербаковская д.3, офис 1107, 1118, ДЦ «Щербаковский»
Телефон: +7 495 668-12-70 (многоканальный)
Факс: +7 495 668-12-70 (доб.304)
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