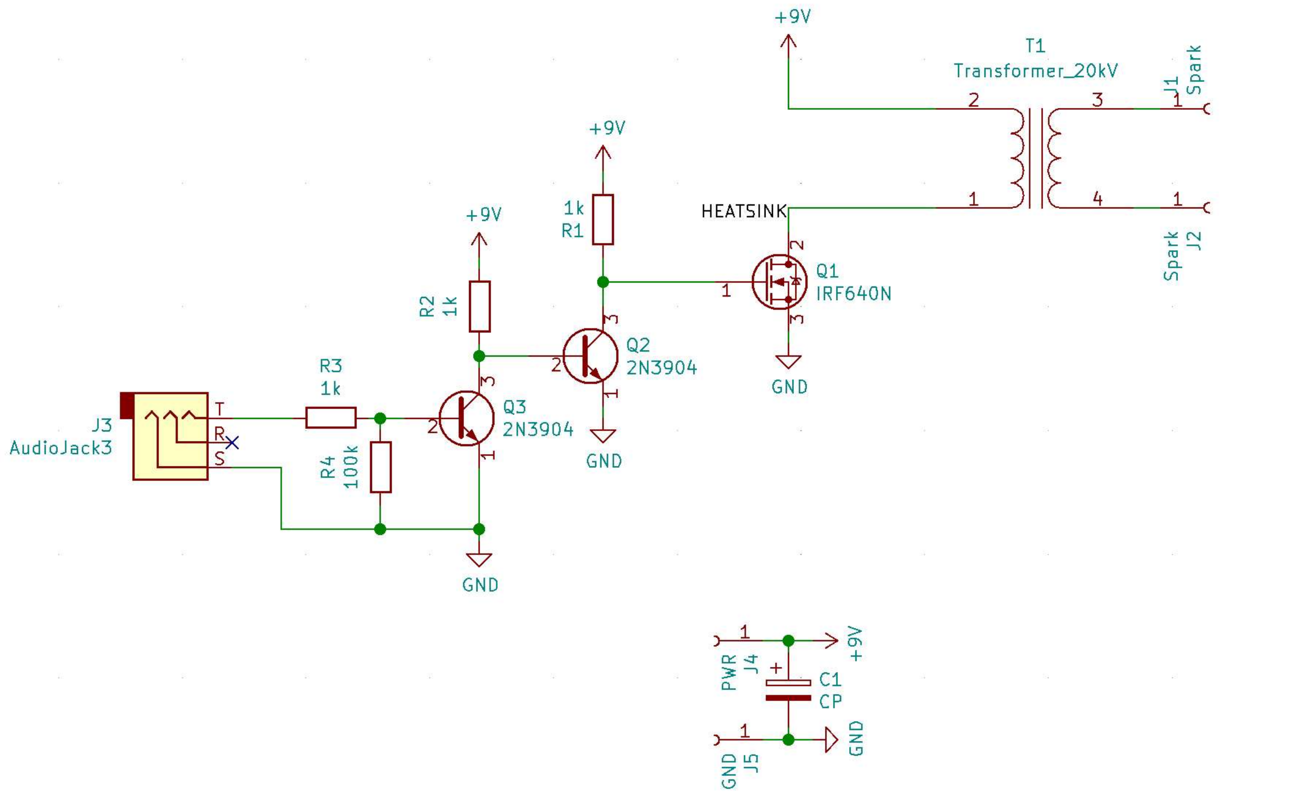
ELECTRICALENGINEERING

Selection of MOSFET for flyback transformer switching circuit

Asked 1 year, 5 months ago Modified 1 year, 5 months ago Viewed 849 times

1

I am working on a project that uses a transformer in flyback mode to create plasma arcing. It's based on a simple circuit that's available in a lot of DIY kits which uses a MOSFET to switch voltage on and off across a transformer:



Main thing here is Q1, which is being used to switch the transformer on and off at a given frequency, creating a variable frequency plasma arc. The rest is just some level shifting. The transformer I'm using has very low resistance across the primary, something like 2-4 ohms, so the main factor here is selecting a MOSFET that can handle a lot of current.

The DIY kit I based this design off of uses an IRF640 MOSFET, but this part is not available from my SMD manufacturer. From their parts library I selected the following transistor, which had the highest power dissipation rating and the lowest drain source resistance: https://datasheet.lcsc.com/lcsc/1809192013_Infineon-Technologies-IRFS4115TRLPBF_C53417.pdf

Is this the right way of thinking about selection for this component, or are there other factors involved that I should be considering?

mosfet transformer components flyback component-selection

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edited Sep 14, 2021 at 18:06

asked Sep 14, 2021 at 17:24

Emmett Palaima
309 1 8

2 *"so the main factor here is selecting a MOSFET that can dissipate a lot of heat."* A normal design procedure would be to minimize the heat produced rather than selecting components which can dissipate it. Have you tried to simulate your circuit? What peak voltage and current did you see? – winny Sep 14, 2021 at 17:31

The resistance of the transformer primary is really low, so it's inherently just a lot of current to be putting through the mosfet. The mosfet switching is replicating an AC power input from a DC supply, and also allowing me to change the frequency of that AC input to created pitched arcing effects. At 4 ohm primary resistance its around 2.25A every time the mosfet turns on. – Emmett Palaima Sep 14, 2021 at 18:11

Resistance of the transformer primary should not be a factor. What will dominate a well designed SMPS in order of relevance will be: output load, magnitizing inductance, switching losses and lastly primary resistance. You didn't answer my question if you have simulated it. – winny Sep 14, 2021 at 18:35

Link the design where you based this on. It's almost certain that you won't have understood it and that any MOSFET you pick will be detonated on flyback voltage. – Andy aka Sep 14, 2021 at 18:46

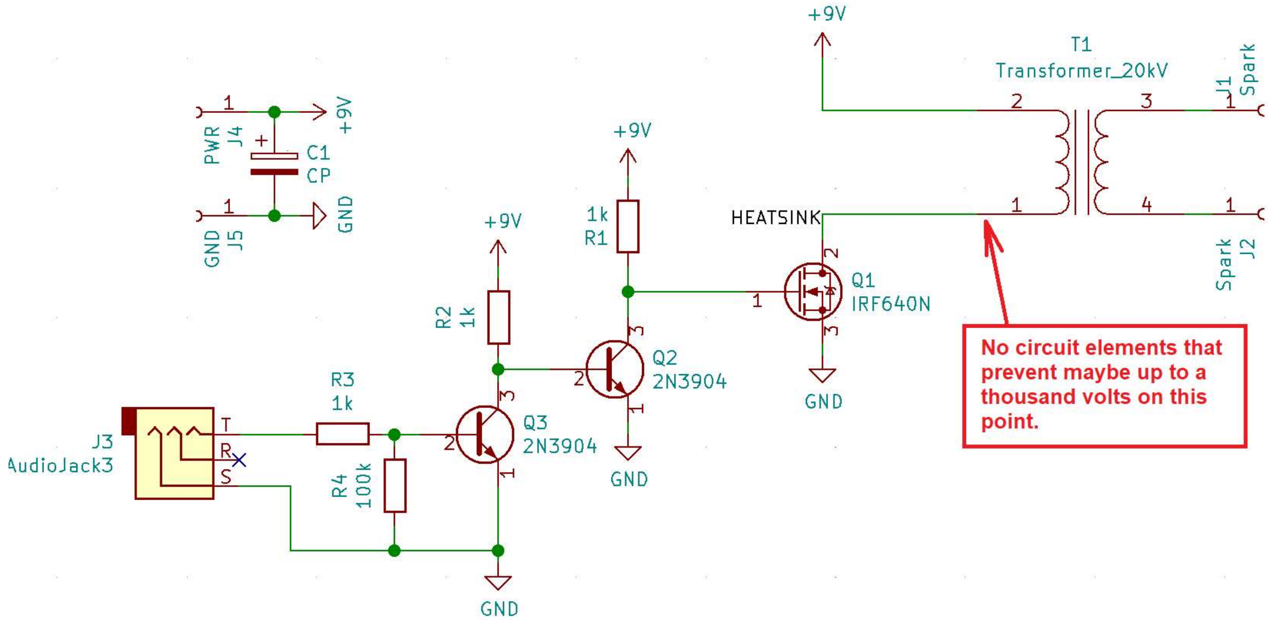
@Andyaka The MOSFET specified in the schematic is a 200V part with a 9V supply voltage, which means there is a very good chance the inductive kickback will not go sufficiently high to damage it. – Edin Fifić Sep 14, 2021 at 18:51

2 Answers

Sorted by: Highest score (default)

3

Your schematic is possibly faulty and you should concentrate on managing the flyback voltage before tackling the actual MOSFET: -



A short story

So, let's say you have a 100:1 step-up transformer with absolutely no leakage inductance between primary and secondary. When the output voltage is (say) 15,000 volts, the reflected drain voltage will be 15,000 divided by 100 = 150 volts. Sounds good until you try and find a transformer with no leakage inductance.

Leakage inductance energy

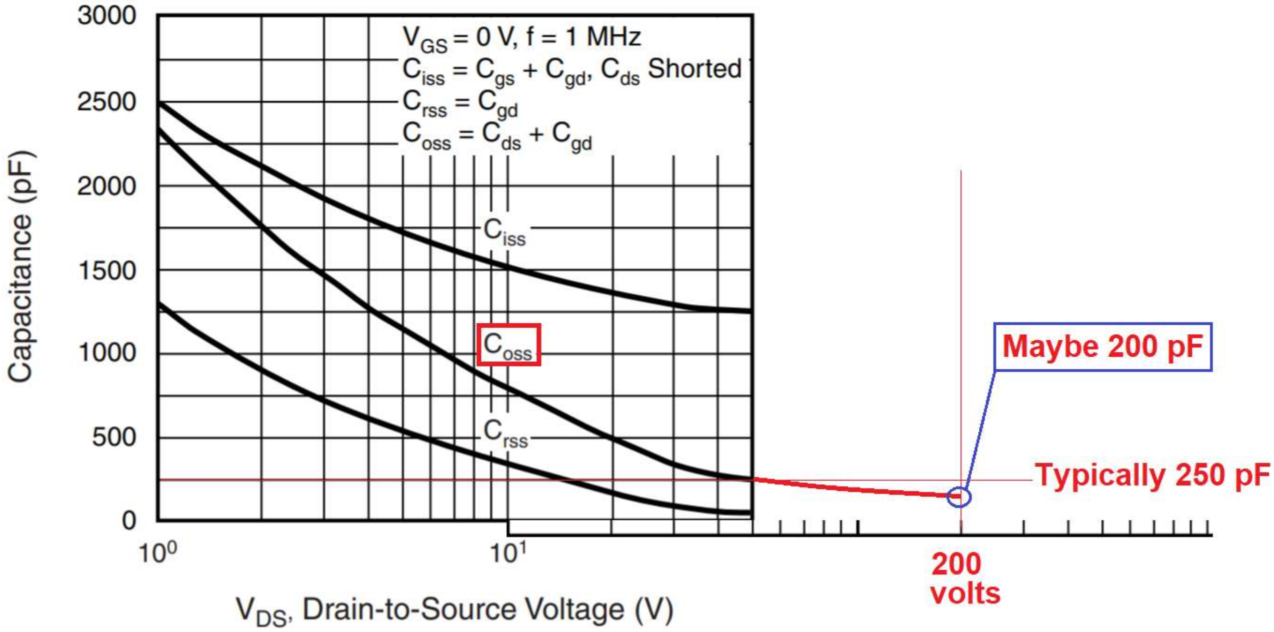
Let's say the primary is 6 turns and the secondary is 600 turns. The primary inductance will be about 30 µH and the leakage inductance might be as high as 5% of that i.e. 1.5 µH. So, given that the primary current might be up to 3 amps, the energy stored in that inductance is $0.5 \cdot L \cdot I^2$ = 6.75 µJ.

[IRF640](https://electronics.stackexchange.com) drain capacitance

The data sheet says 430 pF typically so it might be as low as 300 pF - how much voltage is generated by the leakage inductance energy of 6.75 µJ across 300 pF: -

$$V = \sqrt{\frac{2 \cdot \text{energy}}{C}} = 212 volts$$

But, it's even worse if you look at the data sheet graphs: -



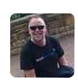
By the time the drain voltage has risen to around 200 volts, the drain-source capacitance may be typically 200 pF and quite possibly as low as 150 pF. Now, with 150 pF, the peak voltage could be as high as **300 volts** and who is to say it might not be 500 volts with a little more leakage inductance or, even a thousand volts. These circuits are notoriously prone to damage and it is the flyback voltage that causes the vast majority of failures and magic smoke.

Conclusion

The design, as it stands is flimsy and you should fix it first before moving on with the MOSFET choice but, it's probably a good idea to check out the output capacitance of a few to see what sort of ball-park capacitance they have. The proposed replacement MOSFET is stated as having an output capacitance of typically 490 pF so, it's going to be in the same ball-park as the IRF640 i.e. problematic but even more so because it's only rated at 150 volts.

Nobody should advise you on the MOSFET choice until you have reasonably demonstrated that you have the flyback voltage properly under control.

Share Cite Follow edited Sep 14, 2021 at 19:35 answered Sep 14, 2021 at 19:26



Andy aka
414k 26 339 730

1 That's some very nice and useful information put together in an easy-to-understand format! I have read a few explanations on the effects of leakage inductance and the expected resulting kick-back voltage's dependence on the shunting capacitance, but none of them have put it in such a short and clear way so as to more easily understand and calculate it. A great bare-bones explanation! I like simple math. – Edin Fifić Sep 14, 2021 at 20:29

Your answer did point to one important difference in Mosfets right away. The voltage rating of the replacement I selected is lower than that of the IRF640. I could see that causing a problem. – Emmett Palaima Sep 14, 2021 at 22:11

How do I properly deal with flyback in this scenario? Whenever I put a flyback diode across the transformer the circuit just stops working. – Emmett Palaima Sep 14, 2021 at 22:12

@EmmettPalaima That is because you are shorting a lot of the flyback's energy with the diode, so a lot less is available at the output. In my answer, I have advised you to use 1-10nF capacitor in series with a 10-100 ohms resistor. Read my whole answer. 1nF/250V capacitor and a 10 ohms 1W resistor should be enough. The capacitor absorbs the voltage spike energy, while the resistor prevents/reduces ringing/oscillations. You could go with a 2.2nF capacitor, but no more if the switching frequency is fairly high because it will be absorbing/wasting too much energy, heating up the resistor. – Edin Fifić Sep 15, 2021 at 1:19

@EmmettPalaima to solve this properly you need to give good details about the transformer being used. This will reveal how much energy is being stored in the windings that cannot be used in the output i.e. the energy that must be quenched. You also should demonstrate how you control the output voltage level because it is that peak voltage that is reflected to the drain node via the turns ratio in reverse. You cannot design a snubber without this information and nobody should make guesses about it. If you want a robust design, you should provide this information. – Andy aka Sep 15, 2021 at 7:04

2

A MOSFET transistor should not be dissipating a lot of heat if it works as a switch, has a very low ON resistance ($R_{DS(on)}$), AND is much faster than the signal that drives it.

In this case, the original transistor had about 0.18 ohms or 180 milli-ohms ON resistance, while the primary has at least 2 ohms, meaning if you ran plain DC current through it, it would be dissipating about 11 times less heat than the transformer primary.

At 9V and 2.2 ohms (total with MOSFET), that would be about 4.1A current, 36.9 watts total, 33.6 W on the primary and about 3W dissipation on the transistor. This would be your worst case scenario, and you would need a large heatsink for the MOSFET. Nearly all MOSFETs in a TO-220 case are capable of dissipating at least 40-50W, provided they have a sufficient heatsink.

The MOSFET you have selected as a replacement has about 10 times lower ON resistance, meaning 10 times lower dissipation/loss than the original, or about 300mW (milli-watts) in which case you don't even need a heatsink.

HOWEVER...

The above-calculated levels of dissipation would happen only if the MOSFET remained ON all the time, or was shorted. The actual current and dissipated power would be much lower, and would depend on the switching frequency, the duty cycle and the INDUCTANCE of the primary (it is this inductance that is the primary limiter of the current during normal operation as it offers much more resistance to high frequency AC - Alternating Current, than to the DC).

The only problem you might have is with the inductive kickback from the primary, which is a voltage spike that happens at the moment when the MOSFET switches off, and it can be many times larger than the supply voltage. From my experience, it is usually about 10 times the supply voltage, and at 12 volts I have measured over 120V spikes, but this depends on the circuit and the components in it.

In your case, the spikes may be well below the 150V rating of your MOSFET, but that's not guaranteed. I would suggest to measure those spikes if you have a scope, and just try the IRFS3415, I believe it will work just fine.

I would suggest you place a snubber made out of a capacitor and a resistor in series, across the primary. The values are typically 1-10nF and 10-100 ohms (1W or so). The capacitor should be rated for at least 150V, but no more than 250V is needed in your case. This snubber should reduce your inductive kickback spikes. In fact, the reason the original schematic requires the MOSFET rated for 200V is because it doesn't include a snubber. With a good snubber, you could get away even with a 60V MOSFET, or even less, but most snubbers waste a small amount of power, so there are trade-offs.

As a last note about MOSFET selection, you can also consider its input capacitance, turn-on and turn-off delay times, and its rise and fall times, but chances are it won't make much difference in this case, depends how high is the driving/switching frequency.

P.S.: At first, you said the primary resistance was 8 ohms, but now it is 2-4 ohms, so I have edited my answer accordingly.

 edited Sep 15, 2021 at 1:07 answered Sep 14, 2021 at 18:15

Edin Fifić
2,664 5 16

A 60 volt mosfet requires a snubber that limits the flyback voltage to about 40 volts and, to achieve a 15,000 volt output naturally requires a nearly three times higher turns ratio on the transformer and makes it much much harder to wind. Nice to see that you listened to my advice in comment about the kickback voltage due to leakage inductance. – Andy aka Sep 14, 2021 at 20:03

Thanks for the advice on the snubber. I was attempting to use a flyback diode across the transformer, but this just caused the entire circuit not to work. Snubber could be the proper fix, I'll try that out. This is based off a cheapo ali-express kit I was experimenting with so I'm sure there is plenty of room for improvement. – Emmett Palaima Sep 14, 2021 at 22:31