

Contents

Contents	1
List of Figures	1
1 Introduction	2
2 Specifications	3
3 Operating Information	4
4 Theory of Operation	5
4.1 Block Description	5
4.2 Detailed Circuit Description	6
Power Input Circuit	6
Switching DC-DC Converters	8
Linear Regulators	9
Microcontroller	10
Synthesizer	10
Synthesizer Output Amplifiers	10
Output System	10
Input System	10
4.3 Software Description	10
Signal Processing	10
User Interface	10
5 Electrical parts	11
6 Full schematics	19
References	33

List of Figures

1	Block diagram	5
2	MOS reverse polarity protection circuit, simplified	6
3	UVLO and OVLO circuit	6
4	Miller integrator	7
5	USB power input circuit	8
6	Basic buck converter circuit	8
7	3.3 V buck converter circuit	9

1 Introduction

2 Specifications

3 Operating Information

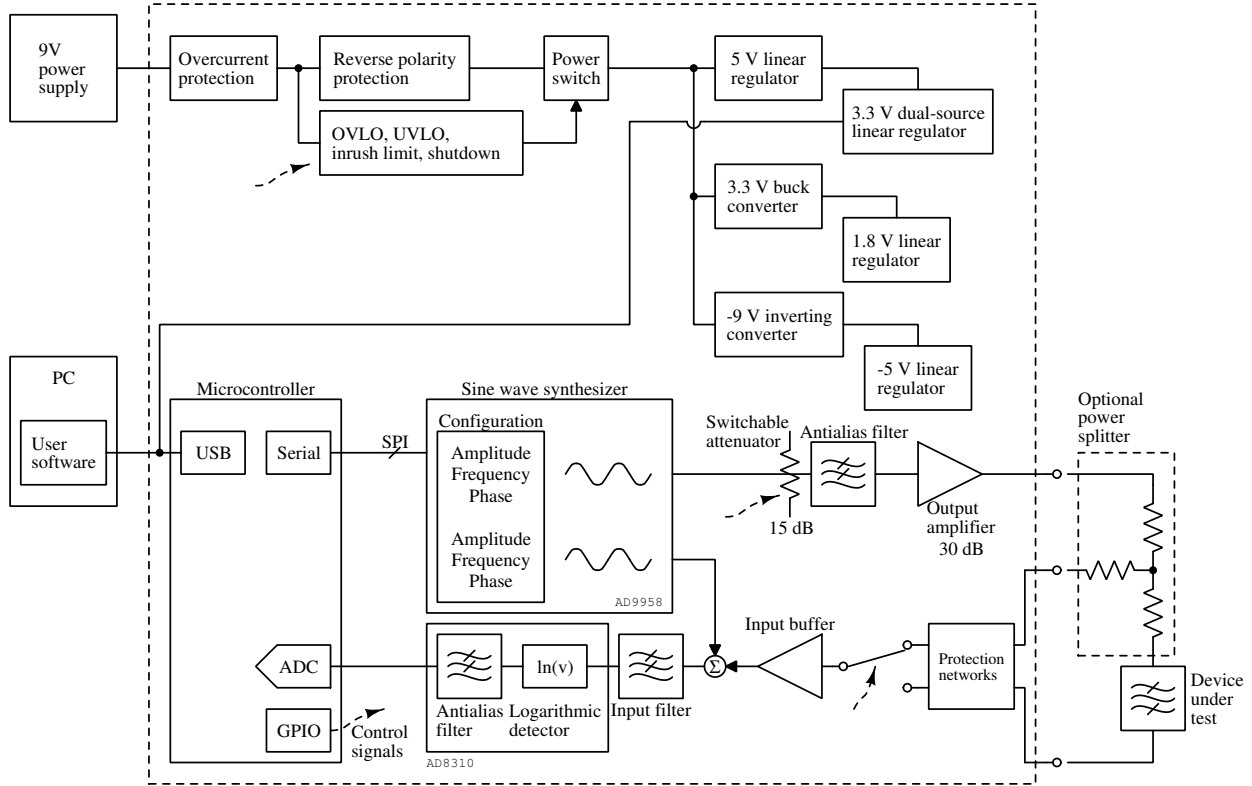


Figure 1: Block diagram

4 Theory of Operation

This section contains a description of the operation of the gain/phase analyzer. Explanations range from simple and broad to very specific. It is expected that the reader has an understanding of the basics of gain/phase analysis itself, which is explained in the [Introduction chapter](#).

Also, it will be beneficial to look at the main system schematics when reading through this section. Small pieces of the schematic are excerpted when helpful in explaining their function, but are not always shown.

4.1 Block Description

The block diagram is shown in figure 1. A microcontroller drives the instrument, configuring a dual sine wave synthesizer via a serial interface. The first output passes through an optional, switchable attenuator, allowing output amplitude to be configured beyond the practical amplitude range of the synthesizer. The signal is then filtered to attenuate Nyquist aliasing, and then amplified by 30 dB before being passed to the output.

Signals returning from the Device Under Test (DUT) pass through input protection networks, then enter a

double-throw RF switch allowing one of them to be analyzed. An input buffer prevents signals from further circuitry from feeding back out the input and affecting the DUT. A summing network combines the input signal with the second output of the synthesizer, and the sum passes through an input filter and into a logarithmic detector. The logarithmic detector outputs a voltage corresponding to the signal amplitude in decibels, and this is further filtered to allow slow sampling, and returns to the microcontroller via the on-chip analog to digital converter.

A power supply system provides overcurrent protection, reverse polarity protection, overvoltage lockout, undervoltage lockout, inrush limiting, and microcontroller-driven shutdown (used in cases of USB suspend). It produces regulated voltage rails of +9 V and -9 V (for the final output amplifier stage), +5 V and -5 V (for general linear circuitry), +3.3 V (for the synthesizer), +1.8 V (for the synthesizer), and a second, weaker +3.3 V rail that can be powered by the USB port in the absence of the main power input (for the microcontroller).

A USB interface connects to a computer, where software sends control commands to the instrument and plots received data.

4.2 Detailed Circuit Description

Power Input Circuit

This instrument is complex and has many somewhat expensive parts, so a full input subsystem was designed to ensure that these parts are always supplied correctly with power. This subsystem provides the following features:

- Overcurrent protection
- Reverse polarity protection
- Undervoltage lockout
- Overvoltage protection
- Inrush current limiting

Overcurrent protection

The first piece of this input system, and possibly the simplest, is R81. R81 is a *resettable fuse*, a type of resistor with a positive temperature coefficient. Its resistance is very low (around $0.5\ \Omega$) at room temperature. As the current flowing through it increases, it heats up, and as it heats up, its resistance increases. Eventually, it will reach a point where this process ‘snowballs’, and its resistance is high enough that almost no current can flow through it. This allows it to act like a fuse, but without permanently blowing: as soon as it cools back down, it will conduct again.

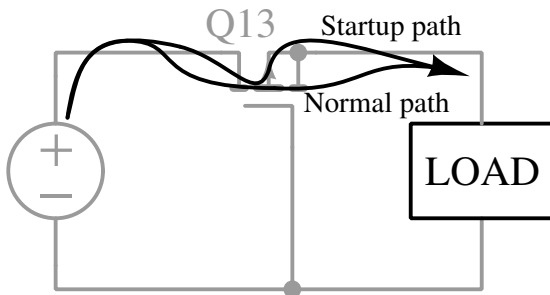


Figure 2: MOS reverse polarity protection circuit, simplified

Reverse polarity protection

Once input current has passed through the resettable fuse, it encounters Q13. A simplified form of this part of the circuit can be seen in figure 2. Remember that a MOSFET has ‘parasitic’ diodes connected from the transistor’s channel to its substrate; in a standard power MOSFET, one ends up connected between the two ends of the channel

(the other ends up shorted to itself). In a P-channel MOSFET, this diode points from the source to the drain. In this circuit, when power is applied with the correct polarity, this diode allows current to initially take the path labeled *startup path*. When it does so, the voltage applied to the load begins to rise, but the gate stays low, as it is tied to ground. Eventually, the voltage rises high enough that the gate-source voltage switches on the MOSFET, and current begins to flow through the *normal path* instead. This path takes the current through the low-impedance MOSFET channel, rather than through the diode where the forward threshold voltage of the diode would be lost.

If power is applied in the incorrect polarity, the substrate diode never conducts, so the MOSFET never switches on.

Power switch

After the reverse polarity protection, the current must flow through Q14, which is connected as a traditional switch. R88 holds its gate and source together when the power is switched off, keeping the MOSFET also turned off.

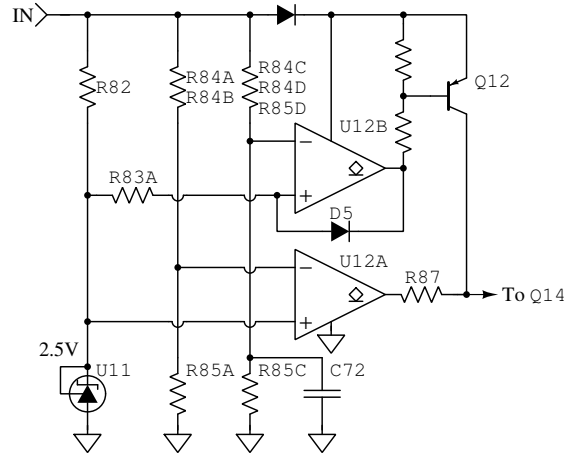


Figure 3: UVLO and OVLO circuit

To simplify things, the subcircuit in figure 3 is powered through a single diode for its own reverse-polarity protection. Bandgap voltage reference U11 does not need this, as its internal circuit has an antiparallel diode built in [8].

Undervoltage lockout

U11 provides an accurate 2.5 V level against which the input voltage can be compared. As the input voltage rises, the voltage at the output of the R84A/R84B/R85A voltage divider also rises. When this divided voltage reaches the

2.5 V reference level, the input voltage is at 7.5 V, the undervoltage threshold. Comparator U12A switches low, allowing power switch Q14 to switch on and allow the full system to operate.

Overvoltage protection

If the input voltage continues to rise, the voltage at the output of the R84C/R84D/R85D/R85C voltage divider will eventually reach the reference level when the input voltage is at 10 V. C72 provides a low-pass effect which prevents simple noise and short transients from causing this. When this happens, comparator U12B switches low. At this point, two things happen. First, Q12 switches Q14 off, powering down the circuit. Second, D5 pulls the reference level as seen by U12B down to about 1 V, locking the system in this shutdown mode until the input voltage drops back as low as 4 V – at which point it must climb again to the 7.5 V undervoltage threshold. In practice, the system must be powered off and back on. This latch prevents the instrument from accidentally being powered by too high an input voltage.

Inrush current limiting

Q14 does not act *only* as a power switch. When it switches on, it starts in the ‘cutoff’ region of operation, and moves to the ‘saturation’ region. However, it must pass through the ‘linear’ region. We can take advantage of this.

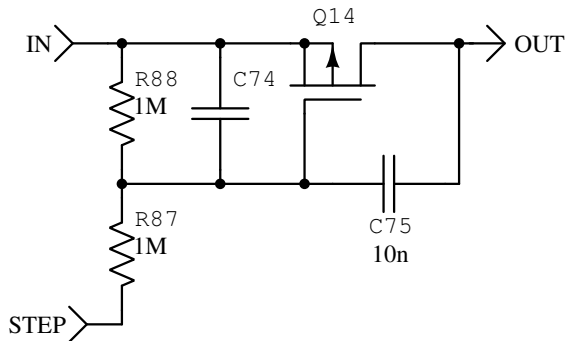


Figure 4: Miller integrator

The circuit in figure 4, when Q14 is in the linear region, is known as a ‘Miller integrator’ [2, pg. 283]. Because R87 and R88 form a voltage divider, the input voltage to the integrator will be half the input supply voltage at half the resistance (nominally, 4.5 V at 500 kΩ). The integrator capacitance is simply C75, which is 10 nF. Because the voltage across C74 changes only negligibly, its effect on the circuit will also be negligible.

At startup, C75 would tend to hold the gate above the source, switching the transistor fully on and bypassing any limiting effect. The much larger C74 swamps this effect, holding the gate to the source until a DC source of current is provided via R87.

The input signal to this integrator will be a step, because comparator U12A switches directly from ‘off’ to ‘on’. Integrating a step gives a ramp, with a slope of:

$$\frac{dv}{dt} = \frac{v_{in}}{RC} = \frac{4.5 \text{ V}}{(500 \text{ k}\Omega)(10 \text{ nF})} = 900 \text{ V/s} = 0.9 \text{ V/ms}$$

This means it will take about 10 ms for the voltage to ramp from zero to the full input voltage of 9 V.

Because the inrush current to be limited is the current charging the system’s capacitance, we can calculate the worst-case inrush current. Charge is held on-board by approximately 200 μF worth of capacitors. Given this capacitance and the voltage slope, the current is calculated as follows:

$$I = C \frac{dv}{dt} = (200 \text{ μF})(900 \text{ V/s}) = 180 \text{ mA}$$

During this charging time, the power dissipated in Q14 will be high. The worst-case is when the full input voltage is dropped across it, giving a power dissipation of (9 V)(180 mA) = 1.62 W. The average power for the entire time will be:

$$\begin{aligned} P &= IV \\ P_{avg} &= \frac{1}{10 \text{ ms}} \int_0^{10 \text{ ms}} i_v dt \\ &= \frac{1}{2} (1.62 \text{ W})(10 \text{ ms}) / (10 \text{ ms}) \\ &= 810 \text{ mW} \end{aligned}$$

Thus, a MOSFET must be selected that can handle an 810 mW pulse for 10 ms. This pulse-handling capability is shown in the datasheet as the “forward-biased safe operating area”, and we selected an AOD417 which can easily handle this pulse with excess [1].

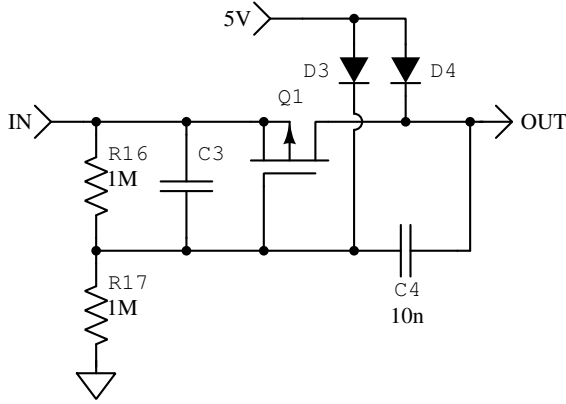


Figure 5: USB power input circuit

USB Power Input Circuit

The USB specification is very demanding with respect to the amount of inrush current that a USB device may consume. We used the same Miller-integrator inrush limiting circuit on the USB power supply input.

In this case, the resistance has not changed (still a Thévenin-equivalent 500 kΩ), and the input step is equal to 2.5 V, half the input voltage. The integrating capacitance is C4, which has a value of 10 nF, and the maximum input capacitance being charged is approximately 20 μF.

$$\frac{dv}{dt} = \frac{v_{in}}{RC} = \frac{2.5 \text{ V}}{(500 \text{ k}\Omega)(10 \text{ nF})} = 500 \text{ V/s}$$

$$I = C \frac{dv}{dt} = (20 \text{ }\mu\text{F})(500 \text{ V/s}) = 10 \text{ mA}$$

The power dissipation in this case is very small (no more than 50 mW for only a few milliseconds), so we used a smaller and less expensive MOSFET that was already in use elsewhere for this particular integrator.

No reverse polarity protection was deemed necessary on the USB input.

Diodes D3 and D4 allow the on-board power supply to power the circuitry downstream from the USB port whenever that supply is powered, so that this circuitry can draw larger amounts of current without the trouble of making sure that this current draw is within USB specifications. D3 shuts off Q1, and D4 provides power in Q1's absence.

Switching DC-DC Converters

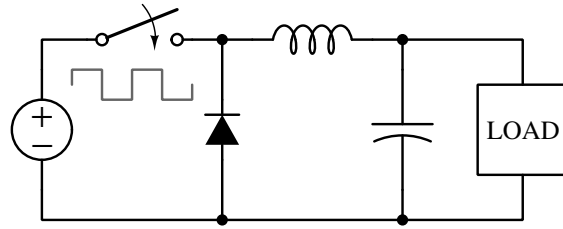


Figure 6: Basic buck converter circuit

Buck converter theory

The basic idea of an inductor is that it translates electric current flowing through it into a magnetic field around it. There is energy stored in this magnetic field, so the inductor tends to hold the current fixed (as changing the current would require adding or removing energy from the field). The 'buck converter' is a voltage down-converter circuit that takes advantage of this.

A more mathematical approach is that inductors integrate the voltage applied to them, producing a current:

$$i = \frac{1}{L} \int v \, dt$$

A buck converter must have at least one switch, as shown in figure 6. The switch is initially closed for a brief period. This applies a positive voltage to the inductor, causing the current through it to begin to increase (remember that the integral of a step is a ramp). This current flows through to the output of the converter, and the output voltage begins to rise.

Now, the switch is opened. The inductor keeps the current flowing, though, through the diode this time. The voltage across the inductor is now negative (the voltage on the left side had to fall negative in order to forward-bias the diode and make it conduct), so the current starts ramping downward, and the output voltage begins to fall. [4, pp. 356–357]

By repeating this cycle, the output voltage can be made to rise and fall around a desired point, and by placing a large capacitor at the output, the rising and falling current can translate to very small variation in output voltage, though it must rise and fall at least a small amount. This allows the output voltage to be any arbitrary voltage smaller than the input voltage, but does not theoretically lose power, unlike a linear regulator (whose entire mechanism of operation is intentional power loss).

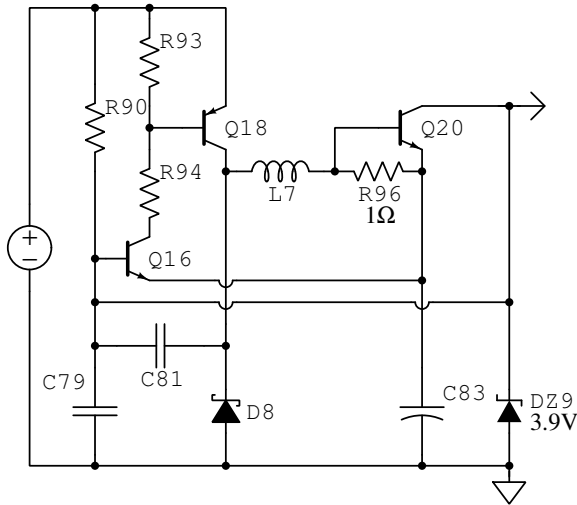


Figure 7: 3.3 V buck converter circuit

3.3 V buck converter

In this instrument, we have used a simple, three-transistor regulated buck converter circuit. It is inexpensive, reliable, and though it is not hugely efficient, it generates relatively little switching noise (due, in part, to its low speed compared to more modern designs).

In the first phase of the switching cycle, Q16's base voltage is low. R90 charges C79, and eventually the base voltage rises high enough that Q16 switches on. It pulls Q18's base voltage down, switching on that transistor too. Q18 is equivalent to the main switch in figure 6, and the inductor current starts to rise.

In the next phase of the switching cycle, something draws current towards ground out of C79 and away from Q16's base. This starts a chain reaction: Q16 and Q18 start to switch off, and are no longer driving the inductor. The inductor's tendency to keep current flowing makes the voltage on its left side sharply decrease. This decrease is coupled through C81, which drags Q16's base voltage even lower, switching it off quite solidly. The converter will remain switched off until C79 charges back up through its resistor.

Two things can be the 'something' of the previous paragraph, initiating the switch from phase 1 to phase 2. First, note that Q16's emitter is connected to the output voltage, so when it is switched on, its base will be about 0.65 V above that. When the output voltage reaches about 3.25 V, the base voltage is at about 3.9 V, and Zener diode DZ9 starts to conduct. This means that the output voltage will not be allowed to rise above about 3.25 V, providing the voltage regulation function.

The inductor current must also flow through sense

resistor R96. If the current exceeds about 650 mA, the base-emitter voltage applied to Q20 will be high enough to switch it on, and Q20 will draw the shutdown current. This provides the current-limiting function.

-9V inverting regulator

It is possible to repurpose a buck converter circuit as an inverting (buck-boost) circuit that generates a negative voltage [9]. The circuit is otherwise the same, with two exceptions. First, the Zener diode, now DZ10, is a 10 V part, giving a regulated output voltage of about 9.35 V. Second, because the current through the output capacitor has more hard edges in a buck-boost converter, a 1 μ F ceramic capacitor (useful to higher frequencies and currents) has been added in parallel with the main output capacitor.

Linear Regulators

A series-type linear regulator works by acting as a controlled resistance, regulating itself to exactly the resistance required to give the correct output voltage considering the amount of current flowing through it. This means that power loss is a required property of linear regulators. For example, a linear regulator taking an input voltage of 9 V, giving an output voltage of 5 V, and passing a current of 100 mA, will lose $(9 - 5)(0.1) \text{ W} = 400 \text{ mW}$ of power, dissipated as heat. The loss is sometimes a fair trade for simplicity and low output noise. This instrument uses four linear regulators, which provide power supplies of 5 V, -5 V, 1.8 V, and a low-power 3.3 V supply (a high-power 3.3 V supply for the synthesizer comes from the buck converter).

These regulators are U13, U14, U15, and U16. They are monolithic devices with no external circuitry except for filter capacitors, and as such will not be addressed further. See their datasheets for more information: [7] [6] [3] [5].

Microcontroller

USB Communications

Synthesizer

Synthesizer Output Amplifiers

Output System

Attenuator and Filter

Gain Stages and Termination

Input System

Protection

Switching

Buffer and Filter

Logarithmic Detector

4.3 Software Description

Signal Processing

Sampling

Null Search

Calibration

User Interface

5 Electrical parts

Reference	Manufacturer	Part Number	Line	Description
C1			CAP MLCC 10n \geq X5R 50V 10% [0603]	
C2			CAP MLCC 10n \geq X5R 50V 10% [0603]	
C3			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C4			CAP MLCC 10n \geq X5R 50V 10% [0603]	
C5			CAP MLCC 10u \geq X5R 10V 10% [0805]	
C6			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C7			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C8			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C9			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C10			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C11			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C12			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C13			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C14			CAP MLCC 15p C0G 50V 10% [0603]	
C15			CAP MLCC 15p C0G 50V 10% [0603]	
C16			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C17			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C18			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C19			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C20			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C21			CAP MLCC 100n \geq X7R 20V 10% [0805]	
C22			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C23			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C24			CAP MLCC 100n \geq X7R 20V 10% [0805]	
C25			CAP MLCC 680p C0G 16V 5% [0603]	
C26			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C27			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C28			CAP MLCC 10u \geq X5R 10V 10% [0805]	
C29			CAP MLCC 10u \geq X5R 10V 10% [0805]	
C30			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C31			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C32			CAP MLCC 1n C0G 50V 10% [0603]	
C33			CAP MLCC 1n C0G 50V 10% [0603]	

Reference	Manufacturer	Part Number	Line	Description
C34			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C35			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C36			CAP MLCC 10u \geq X5R 10V 10% [0805]	
C37			CAP MLCC 10u \geq X5R 10V 10% [0805]	
C38			CAP MLCC 100n \geq X7R 20V 10% [0805]	
C39			CAP MLCC 100n \geq X7R 20V 10% [0805]	
C40			CAP MLCC 10u \geq X5R 25V 10% [1206]	
C41			CAP MLCC 10u \geq X5R 25V 10% [1206]	
C43	Murata	GRM1555C1H220GA01D	DIST DIGIKEY 490-6219-1-ND	CAP MLCC 22pF C0G [0402]
C44	Murata	GRM1555C1H220GA01D	DIST DIGIKEY 490-6219-1-ND	CAP MLCC 22pF C0G [0402]
C45	Samsung	CL10C1R5BB8NNNC	DIST DIGIKEY 1276-1656-1-ND	CAP MLCC 1.5pF C0G [0402]
C46	Samsung	CL05C560JB5NNNC	DIST DIGIKEY 1276-1707-1-ND	CAP MLCC 56pF C0G [0402]
C47	Samsung	CL05C4R7CB5NNNC	DIST DIGIKEY 1276-1703-1-ND	CAP MLCC 4.7pF C0G [0402]
C48	Samsung	CL05C4R7CB5NNNC	DIST DIGIKEY 1276-1703-1-ND	CAP MLCC 4.7pF C0G [0402]
C49	Samsung	CL05C560JB5NNNC	DIST DIGIKEY 1276-1707-1-ND	CAP MLCC 56pF C0G [0402]
C50	Samsung	CL05C4R7CB5NNNC	DIST DIGIKEY 1276-1703-1-ND	CAP MLCC 4.7pF C0G [0402]
C51	Murata	GRM1555C1H220GA01D	DIST DIGIKEY 490-6219-1-ND	CAP MLCC 22pF C0G [0402]
C52	Murata	GRM1555C1H220GA01D	DIST DIGIKEY 490-6219-1-ND	CAP MLCC 22pF C0G [0402]
C53			CAP MLCC 47u \geq X5R 10V 20% [1206]	
C54			CAP MLCC 1n C0G 50V 10% [0603]	
C55			CAP MLCC 220n \geq X5R 16V 10% [0805]	
C56			CAP MLCC 10n \geq X5R 50V 10% [0603]	
C57			CAP MLCC 1n C0G 50V 10% [0603]	
C58			CAP MLCC 1n C0G 50V 10% [0603]	
C59			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C60	TDK	C1608C0G1H220F080AA	DIST DIGIKEY 445-5366-1-ND	CAP MLCC 22pF C0G [0402]
C61	TDK	C1608C0G1H330F080AA	DIST DIGIKEY 445-7027-1-ND	CAP MLCC 33pF C0G [0402]
C62	TDK	C1608C0G1H220F080AA	DIST DIGIKEY 445-5366-1-ND	CAP MLCC 22pF C0G [0402]
C63			CAP MLCC 10n \geq X5R 50V 10% [0603]	
C64	TDK	C2012JB1H105K085AB	DIST DIGIKEY 445-11490-1-ND	CAP MLCC 1uF [0805]
C65			CAP MLCC 10n \geq X5R 50V 10% [0603]	
C66	TDK	C2012JB1H105K085AB	DIST DIGIKEY 445-11490-1-ND	CAP MLCC 1uF [0805]
C67			CAP MLCC 10n \geq X5R 50V 10% [0603]	
C68			CAP MLCC 100n \geq X7R 16V 10% [0603]	
C69			CAP MLCC 47u \geq X5R 10V 20% [1206]	
C70			CAP MLCC 220p C0G 16V 5% [0603]	
C71			CAP MLCC 330n \geq X7R 50V 5% [0603]	

Reference	Manufacturer	Part Number	Line	Description
C72			CAP MLCC 10n \geq X5R 50V 10% [0603]	
C73			CAP MLCC 100n \geq X5R 16V 10% [0805]	
C74			CAP MLCC 100n \geq X5R 16V 10% [0805]	
C75			CAP MLCC 10n \geq X5R 50V 10% [0603]	
C76	Panasonic	16SVPC100M	DIST DIGIKEY P16468CT-ND	CAP ALU-POLY 100uF 16V
C77	Panasonic	16SVPC100M	DIST DIGIKEY P16468CT-ND	CAP ALU-POLY 100uF 16V
C78			CAP MLCC 10n \geq X5R 50V 10% [0603]	
C79			CAP MLCC 10n \geq X5R 50V 10% [0603]	
C80			CAP MLCC 1n C0G 50V 10% [0603]	
C81			CAP MLCC 1n C0G 50V 10% [0603]	
C82	Panasonic	16SVPC100M	DIST DIGIKEY P16468CT-ND	CAP ALU-POLY 100uF 16V
C83	Panasonic	16SVPC100M	DIST DIGIKEY P16468CT-ND	CAP ALU-POLY 100uF 16V
C84			CAP MLCC 1uF \geq X5R 16V 10% [1206]	
C85			CAP MLCC 1uF \geq X5R 16V 10% [1206]	
C86			CAP MLCC 10n \geq X5R 25V 10% [0402]	
C87			CAP MLCC 1nF C0G 10V 5% [0402]	
C89			CAP MLCC 1uF \geq X5R 16V 10% [1206]	
C90			CAP MLCC 10u \geq X5R 10V 10% [0805]	
C91			CAP MLCC 10u \geq X5R 10V 10% [0805]	
C92			CAP MLCC 22u \geq X5R 6V 10% [0805]	
C93			CAP MLCC 1uF \geq X5R 10V 10% [0805]	
C97			CAP MLCC 100nF \geq X5R 10V 10% [0603]	
C98			CAP MLCC 100nF \geq X5R 10V 10% [0603]	
C100			CAP MLCC 100nF \geq X5R 10V 10% [0603]	
C101			CAP MLCC 100nF \geq X5R 10V 10% [0603]	
C102			CAP MLCC 100nF \geq X5R 10V 10% [0603]	
C103			CAP MLCC 100nF \geq X5R 10V 10% [0603]	
C104			CAP MLCC 100nF \geq X5R 10V 10% [0603]	
C105			CAP MLCC 100nF \geq X5R 10V 10% [0603]	
C106			CAP MLCC 100nF \geq X5R 10V 10% [0603]	
C107			CAP MLCC 10u \geq X5R 10V 10% [0805]	
C108			CAP MLCC 10u \geq X5R 10V 10% [0805]	
C109			CAP MLCC 1uF \geq X5R 10V 10% [0805]	
C110			CAP MLCC 15p C0G 50V 10% [0603]	
C111			CAP MLCC 15p C0G 50V 10% [0603]	
D7			SEMI GENERIC MBR0540	
D8			SEMI GENERIC MBR0540	

Reference	Manufacturer	Part Number	Line	Description
DS2			SEMI GENERIC LED RED [0603]	
DS3			SEMI GENERIC LED RED [0603]	
DS4			SEMI GENERIC LED RED [0603]	
DS5			SEMI GENERIC LED RED [0603]	
DS6			SEMI GENERIC LED RED [0603]	
DS7			SEMI GENERIC LED RED [0603]	
DS8			SEMI GENERIC LED RED [0603]	
DS9			SEMI GENERIC LED RED [0603]	
DS10			SEMI GENERIC LED RED [0603]	
DS11			SEMI GENERIC LED RED [0603]	
DZ1	ONsemi	1SMA5914BT3G	SEMI ONSEMI 1SMA5914BT3G	
DZ2	Littelfuse	SP0503BAHTG	SEMI LITTELFUSE SP0503BAHT	
DZ3	ONsemi	ESD9L5.0ST5G	SEMI ONSEMI ESD9L5.0ST5G	
DZ4	ONsemi	ESD9L5.0ST5G	SEMI ONSEMI ESD9L5.0ST5G	
DZ5		BZX84C2V7	SEMI GENERIC BZX84C2V7	
DZ6		BZX84C2V7	SEMI GENERIC BZX84C2V7	
DZ7	ONsemi	ESD9L5.0ST5G	SEMI ONSEMI ESD9L5.0ST5G	
DZ8	ONsemi	ESD9L5.0ST5G	SEMI ONSEMI ESD9L5.0ST5G	
E1	Laird	HZ0805B222R-10	DIST DIGIKEY 240-2562-1-ND	FERRITE CHIP 2.2k @ 100MHz [0805]
E2	Laird	HZ0805B222R-10	DIST DIGIKEY 240-2562-1-ND	FERRITE CHIP 2.2k @ 100MHz [0805]
E5	Bourns	MZ1608-102Y	DIST DIGIKEY MZ1608-102YCT-ND	FERRITE CHIP 1k @ 100MHz [0603]
J1	CUI	PJ-037A	DIST DIGIKEY CP-037A-ND	CONN BARREL 2x6.5MM
J2	TE	5-1814400-1	DIST DIGIKEY A97593-ND	CONN SMA RIGHTANGLE FEMALE
J3	TE	5-1814400-1	DIST DIGIKEY A97593-ND	CONN SMA RIGHTANGLE FEMALE
J4	TE	5-1814400-1	DIST DIGIKEY A97593-ND	CONN SMA RIGHTANGLE FEMALE
J6	FCI	10118194-0001LF	DIST DIGIKEY 609-4618-1-ND	CONN USB MICRO-B FEMALE
L1	Samsung	CIH05T56NJNC	DIST DIGIKEY 1276-6281-1-ND	IND CHIP 56nH
L2	Samsung	CIH05T47NJNC	DIST DIGIKEY 1276-6280-1-ND	IND CHIP 47nH
L3	Samsung	CIH05T47NJNC	DIST DIGIKEY 1276-6280-1-ND	IND CHIP 47nH
L4	Panasonic	ELJ-RF39NGFB	DIST DIGIKEY PCD1917CT-ND	IND CHIP 39nH
L5	Panasonic	ELJ-RF39NGFB	DIST DIGIKEY PCD1917CT-ND	IND CHIP 39nH
L7	Bourns	RLB0914-221KL	DIST DIGIKEY RLB0914-221KL-ND	IND WOUND 220uH 700mA
L8	TDK	MLZ2012M4R7HT000	DIST DIGIKEY 445-8659-1-ND	IND CHIP 4.7uH 300mA [0805]
L9	TDK	MLZ2012M4R7HT000	DIST DIGIKEY 445-8659-1-ND	IND CHIP 4.7uH 300mA [0805]
L10	TDK	MLZ2012M4R7HT000	DIST DIGIKEY 445-8659-1-ND	IND CHIP 4.7uH 300mA [0805]
MP5	Laird	BMI-S-203F	DIST DIGIKEY 903-1052-1-ND	RF SHIELD TWO-PIECE
MP5	Laird	BMI-S-203-C	DIST DIGIKEY 903-1015-ND	RF SHIELD TWO-PIECE

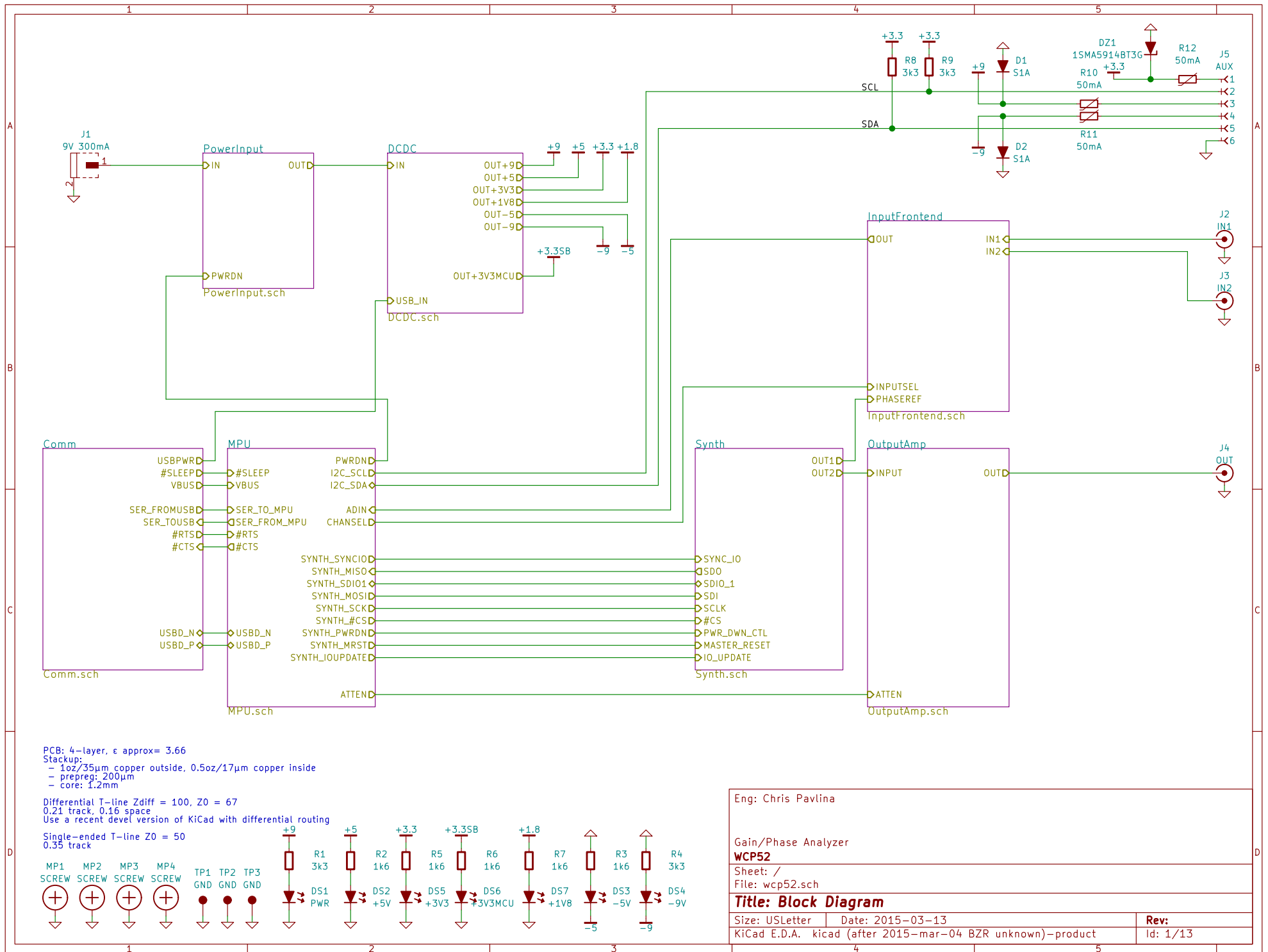
Reference	Manufacturer	Part Number	Line	Description
Q1	IRF	IRLML6402TRPBF	SEMI IRF IRLML6402	
Q8			SEMI GENERIC MMBT3904	
Q9	NXP	BFR540,215	SEMI NXP BFR540	
Q10	NXP	BFR540,215	SEMI NXP BFR540	
Q11			SEMI GENERIC MMBT3904	
Q12			SEMI GENERIC MMBT3906	
Q13			SEMI GENERIC MMBT3904	
Q15			SEMI GENERIC MMBT3904	
Q16			SEMI GENERIC MMBT3904	
Q17			SEMI GENERIC PZT2907A	
Q18			SEMI GENERIC PZT2907A	
Q19			SEMI GENERIC MMBT3904	
Q20			SEMI GENERIC MMBT3904	
R1			RES SMD 3.3k 5% [0603]	
R2			RES SMD 1.6k 1% [0603]	
R3			RES SMD 1.6k 1% [0603]	
R4			RES SMD 3.3k 5% [0603]	
R5			RES SMD 1.6k 1% [0603]	
R6			RES SMD 1.6k 1% [0603]	
R7			RES SMD 1.6k 1% [0603]	
R8			RES SMD 3.3k 5% [0603]	
R9			RES SMD 3.3k 5% [0603]	
R10	Bel Fuse	0ZCJ0005FF2E	DIST DIGIKEY 507-1793-1-ND	PPTC 50mA/150mA 60V [1206]
R11	Bel Fuse	0ZCJ0005FF2E	DIST DIGIKEY 507-1793-1-ND	PPTC 50mA/150mA 60V [1206]
R12	Bel Fuse	0ZCJ0005FF2E	DIST DIGIKEY 507-1793-1-ND	PPTC 50mA/150mA 60V [1206]
R13			RES SMD 1M 5% [0603]	
R14			RES SMD 22 5% [0603]	
R15			RES SMD 22 5% [0603]	
R16			RES SMD 1M 5% [0603]	
R17			RES SMD 1M 5% [0603]	
R18			RES SMD 49.9 1% [0603]	
R19			RES SMD 1.91k 1% [0603]	
R21			RES SMD 49.9 1% [0603]	
R22			RES SMD 49.9 1% [0603]	
R23			RES SMD 49.9 1% [0603]	
R24			RES SMD 53.6 1% [0603]	
R25			RES SMD 53.6 1% [0603]	

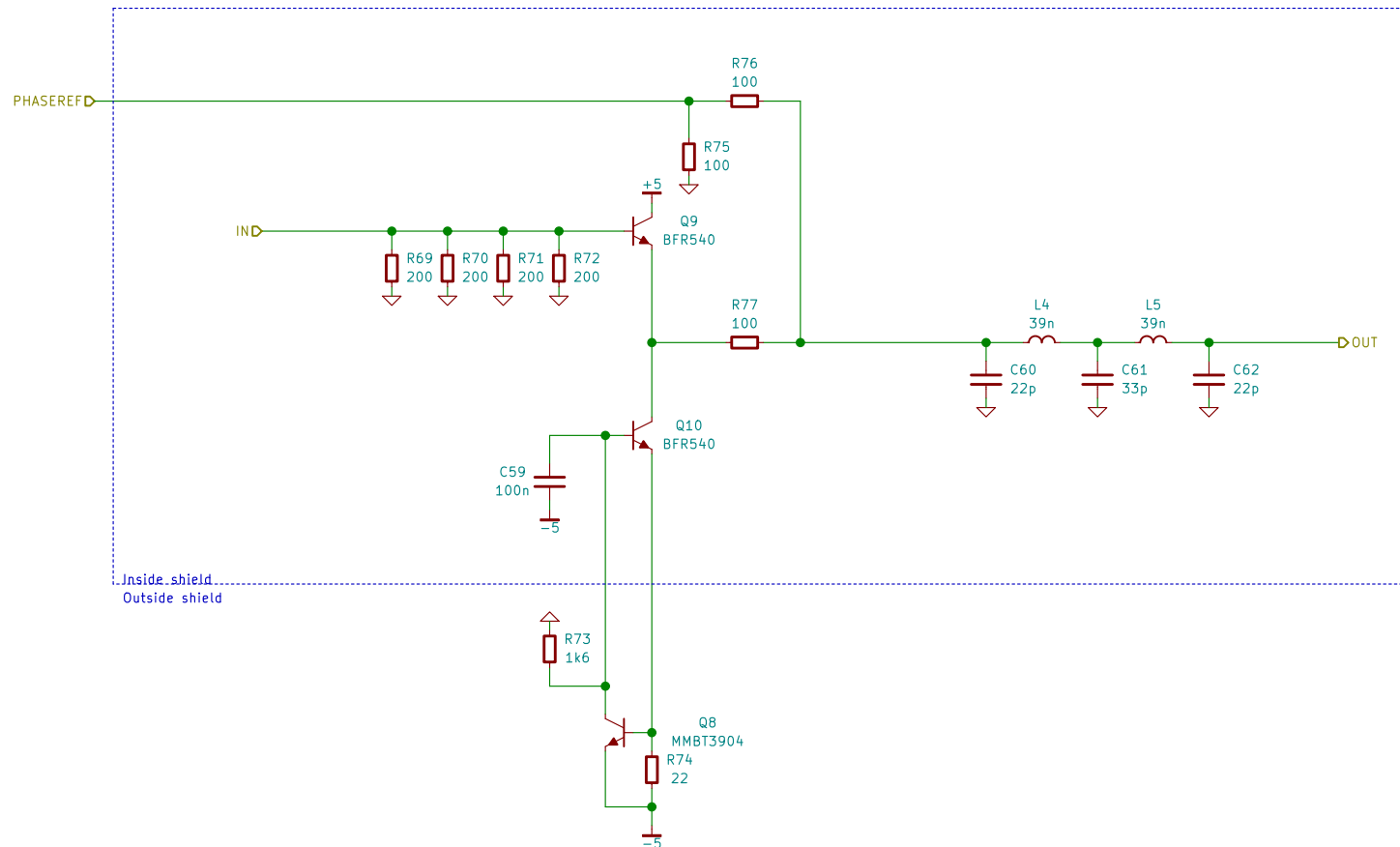
Reference	Manufacturer	Part Number	Line	Description
R26			RES SMD 53.6 1% [0603]	
R27			RES SMD 53.6 1% [0603]	
R28			RES SMD 360 1% [0603]	
R29			RES SMD 360 1% [0603]	
R30			RES SMD 360 1% [0603]	
R31			RES SMD 360 1% [0603]	
R32			RES SMD 360 1% [0603]	
R33			RES SMD 360 1% [0603]	
R34			RES SMD 360 1% [0603]	
R35			RES SMD 360 1% [0603]	
R36			RES SMD 1.91k 1% [0603]	
R37			RES SMD 1.91k 1% [0603]	
R38			RES SMD 49.9 1% [0603]	
R39			RES SMD 49.9 1% [0603]	
R40			RES SMD 1.6k 1% [0603]	
R41	Yageo	YC164-JR-0710KL	DIST DIGIKEY YC164J-10KCT-ND	RESPACK SMD 10k 5% [4x0603]
R42			RES SMD 200 1% [0603]	
R43			RES SMD 200 1% [0603]	
R45			RES SMD 30 1% [0603]	
R46			RES SMD 49.9 1% [0603]	
R47			RES SMD 150 1% [0603]	
R48			RES SMD 750 1% [0603]	
R49			RES SMD 150 1% [0603]	
R50			RES SMD 33 1% [0603]	
R51			RES SMD 33 1% [0603]	
R52			RES SMD 33 1% [0603]	
R53			RES SMD 33 1% [0603]	
R54			RES SMD 33 1% [0603]	
R55			RES SMD 33 1% [0603]	
R56			RES SMD 49.9 1% [0603]	
R57			RES SMD 1.6k 1% [0603]	
R58			RES SMD 1.6k 1% [0603]	
R59			RES SMD 3.3 5% [0603]	
R60			RES SMD 750 1% [0603]	
R61			RES SMD 750 1% [0603]	
R62			RES SMD 1.6k 1% [0603]	
R63			RES SMD 1.6k 1% [0603]	

Reference	Manufacturer	Part Number	Line	Description
R64			RES SMD 3.3 5% [0603]	
R65			RES SMD 1.6k 1% [0603]	
R66	Yageo	YC164-JR-0710KL	DIST DIGIKEY YC164J-10KCT-ND	RESPACK SMD 10k 5% [4x0603]
R67			RES SMD 200 1% [0603]	
R68			RES SMD 200 1% [0603]	
R69			RES SMD 200 1% [0603]	
R70			RES SMD 200 1% [0603]	
R71			RES SMD 200 1% [0603]	
R72			RES SMD 200 1% [0603]	
R73			RES SMD 1.6k 1% [0603]	
R74			RES SMD 22 5% [0603]	
R75			RES SMD 100 1% [0603]	
R76			RES SMD 100 1% [0603]	
R77			RES SMD 100 1% [0603]	
R78			RES SMD 3.3k 5% [0603]	
R79			RES SMD 53.6 1% [0603]	
R80			RES SMD 49.9 1% [0603]	
R81	BelFuse	0ZCJ0035AF2E	DIST DIGIKEY 507-1801-1-ND	PPTC 350mA/750mA 30V [1206]
R82			RES SMD 1k 5% [0402]	
R83			RES SMD 1k 5% [0402]	
R84			RES SMD 1k 5% [0402]	
R85			RES SMD 1 5% [1210]	
R86			RES SMD 3.3k 5% [0603]	
R87			RES SMD 1M 5% [0603]	
R88			RES SMD 1M 5% [0603]	
R89			RES SMD 3.3k 5% [0603]	
R90			RES SMD 3.3k 5% [0603]	
R91			RES SMD 1.6k 1% [0603]	
R92			RES SMD 750 1% [0603]	
R93			RES SMD 1.6k 1% [0603]	
R94			RES SMD 750 1% [0603]	
R95			RES SMD 1 5% [1210]	
R96			RES SMD 1 5% [1210]	
R97	BelFuse	0ZCJ0010FF2E	DIST DIGIKEY 507-1794-1-ND	PPTC 100mA/250mA 60V [1206]
R98			RES SMD 3.3 10% [0603]	
R99			RES SMD 3.3 10% [0603]	
R102			RES SMD 3.3k 5% [0603]	

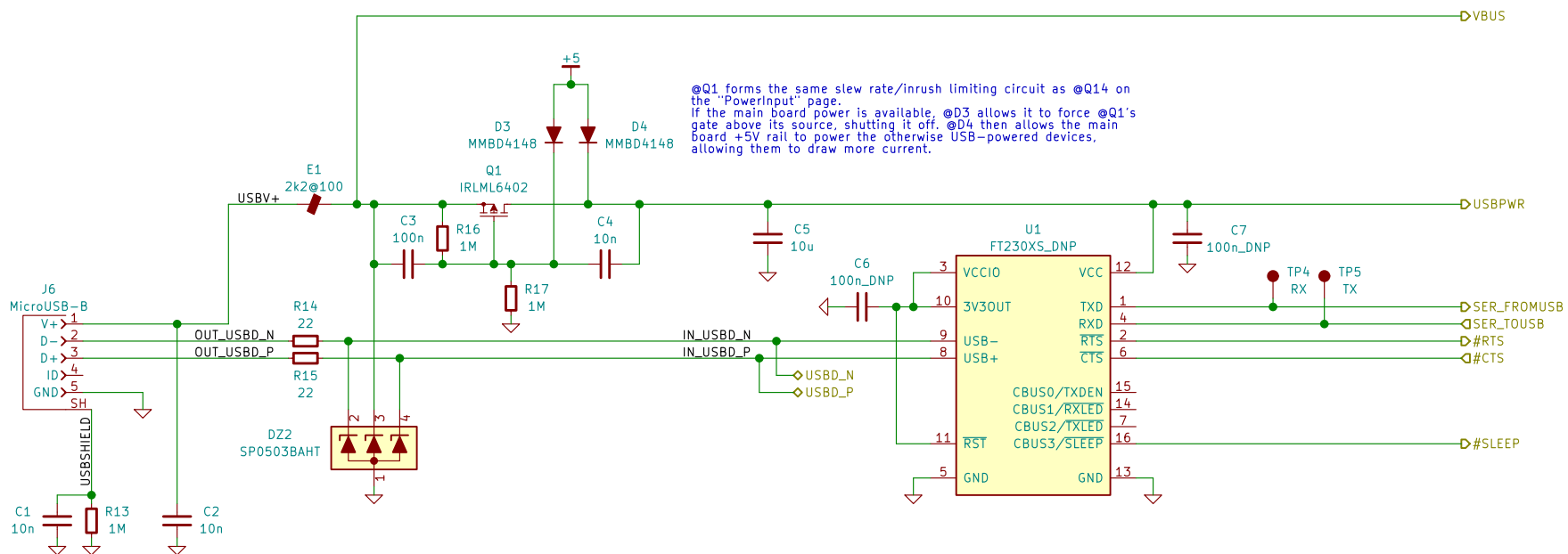
Reference	Manufacturer	Part Number	Line	Description
R103			RES SMD 3.3k 5% [0603]	
R104			RES SMD 3.3k 5% [0603]	
R105			RES SMD 3.3k 5% [0603]	
R106			RES SMD 1k 5% [0603]	
R107			RES SMD 1k 5% [0603]	
R108			RES SMD 1k 5% [0603]	
R109			RES SMD 1k 5% [0603]	
R110			RES SMD 200 1% [0603]	
R111			RES SMD 3.3k 5% [0603]	
R112			RES SMD 200 1% [0603]	
R113			RES SMD 200 1% [0603]	
R114			RES SMD 200 1% [0603]	
R115			RES SMD 200 1% [0603]	
R116			RES SMD 200 1% [0603]	
R117			RES SMD 360 1% [0603]	
U1	FTDI	FT230XS-R	IC FTDI FT230XS	
U2			IC TI LMH6714MF	
U4			IC TI LMH6714MF	
U5			IC ADI AD8000YRDZ	
U6			IC TI THS3001IDGN	
U7			IC MACOM MAADSS0008	
U8	MACom	MASWSS0162TR-3000	IC MACOM MASWSS0162	
U9	MACom	MASWSS0162TR-3000	IC MACOM MASWSS0162	
U10	AnalogDevices	AD8310ARMZ	IC ADI AD8310ARMZ	
U13	ST	L78M05CDT	IC ST L78M05CDT	
U14	ONSem	MC79M05CDTG	IC ONSEMI MC79M05CDTG	
U15	DiodesInc	AZ1117CH-1.8TRG1	IC DIODES AZ1117CH-1.8TRG1	
U16	Microchip	MCP1700T-3302E/TT	IC MICROCHIP MCP1700T-3302E/TT	
U18	Atmel	ATSAM4S16CA-AU	IC ATMEL ATSAM4S16CA-AU	
X1	TXC	9C-25.000MEEJ-T	DIST DIGIKEY 887-1283-1-ND	CRYSTAL 25MHz 18pF 10PPM
X2	Abrakon	ABLS-12.000MHZ-B4-T	DIST DIGIKEY 535-10218-1-ND	CRYSTAL 12MHz 18pF

6 Full schematics





Eng: Chris Pavlina		
Gain/Phase Analyzer		
WCP52		
Sheet: /InputFrontend/Buffer_Filter/		
File: Buffer_Filter.sch		
Title: Input Buffer and Filter		
Size: USLetter	Date: 2015-03-13	Rev:
KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product		Id: 9/13



@Q1 forms the same slew rate/inrush limiting circuit as @Q14 on the "PowerInput" page.
 If the main board power is available, @D3 allows it to force @Q1's gate above its source, shutting it off. @D4 then allows the main board +5V rail to power the otherwise USB-powered devices, allowing them to draw more current.

Eng: Chris Pavlina

Gain/Phase Analyzer
WCP52

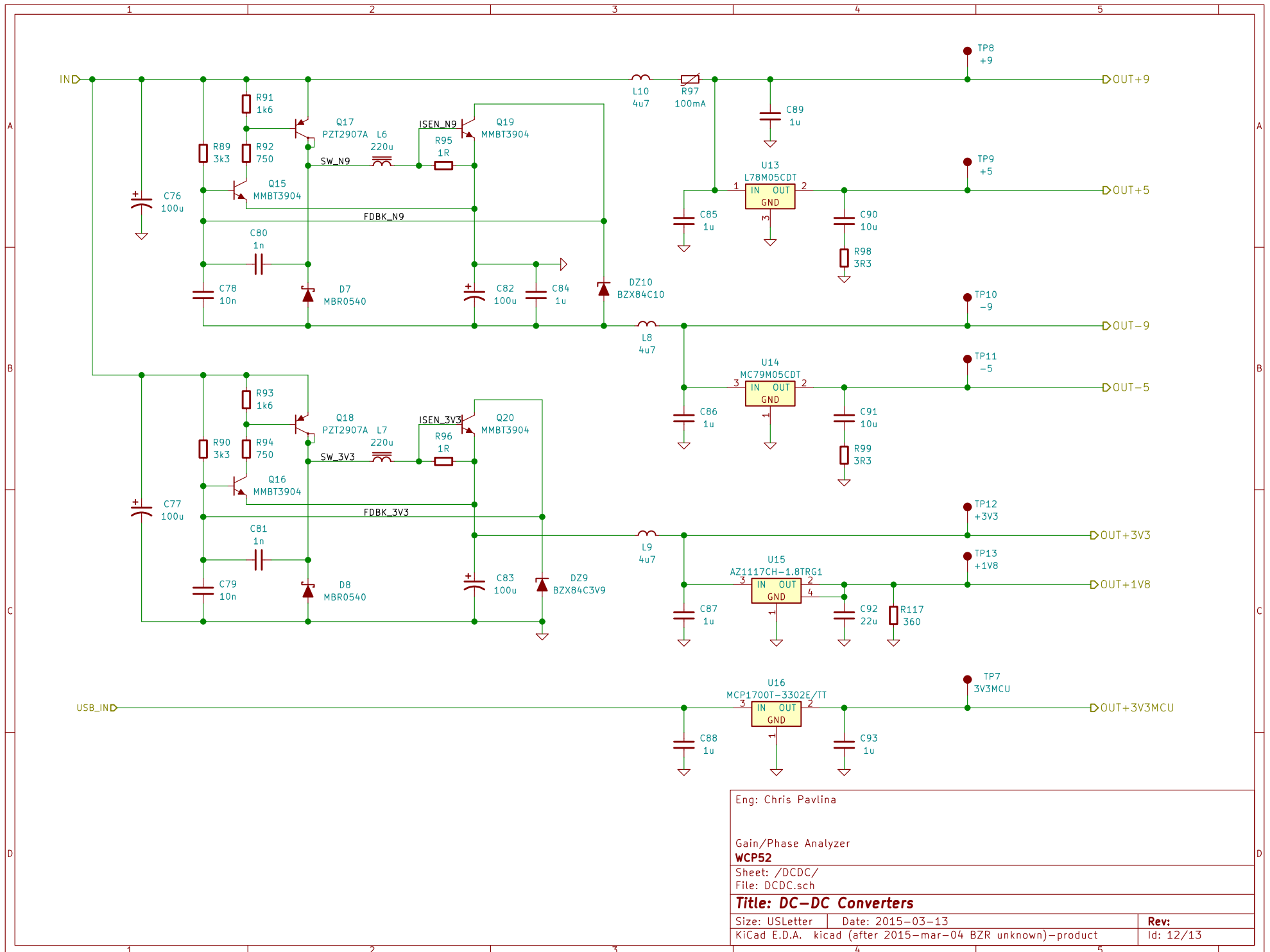
Sheet: /Comm/
File: Comm.sch

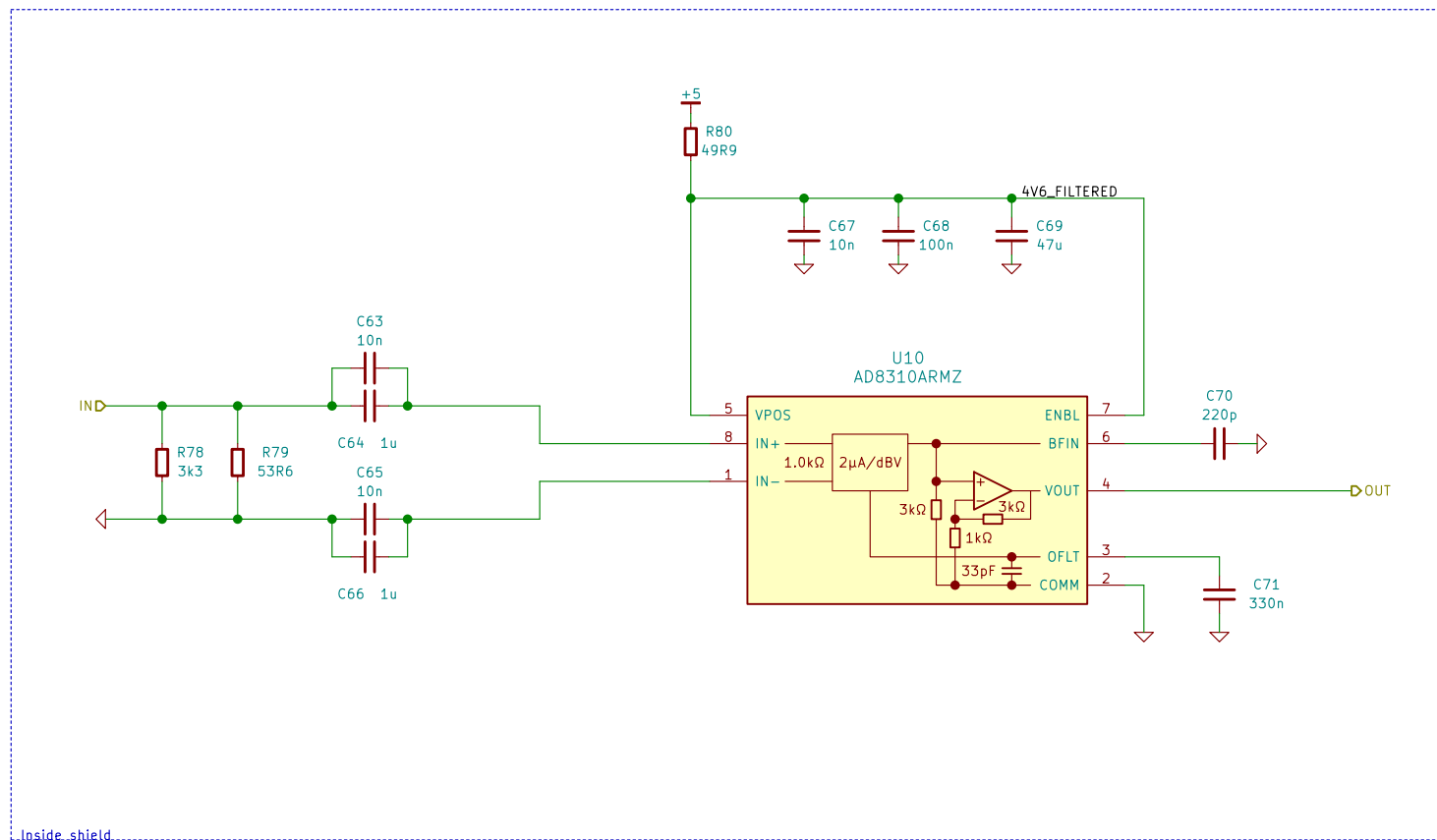
Title: USB Communications

Size: USLetter Date: 2015-03-13

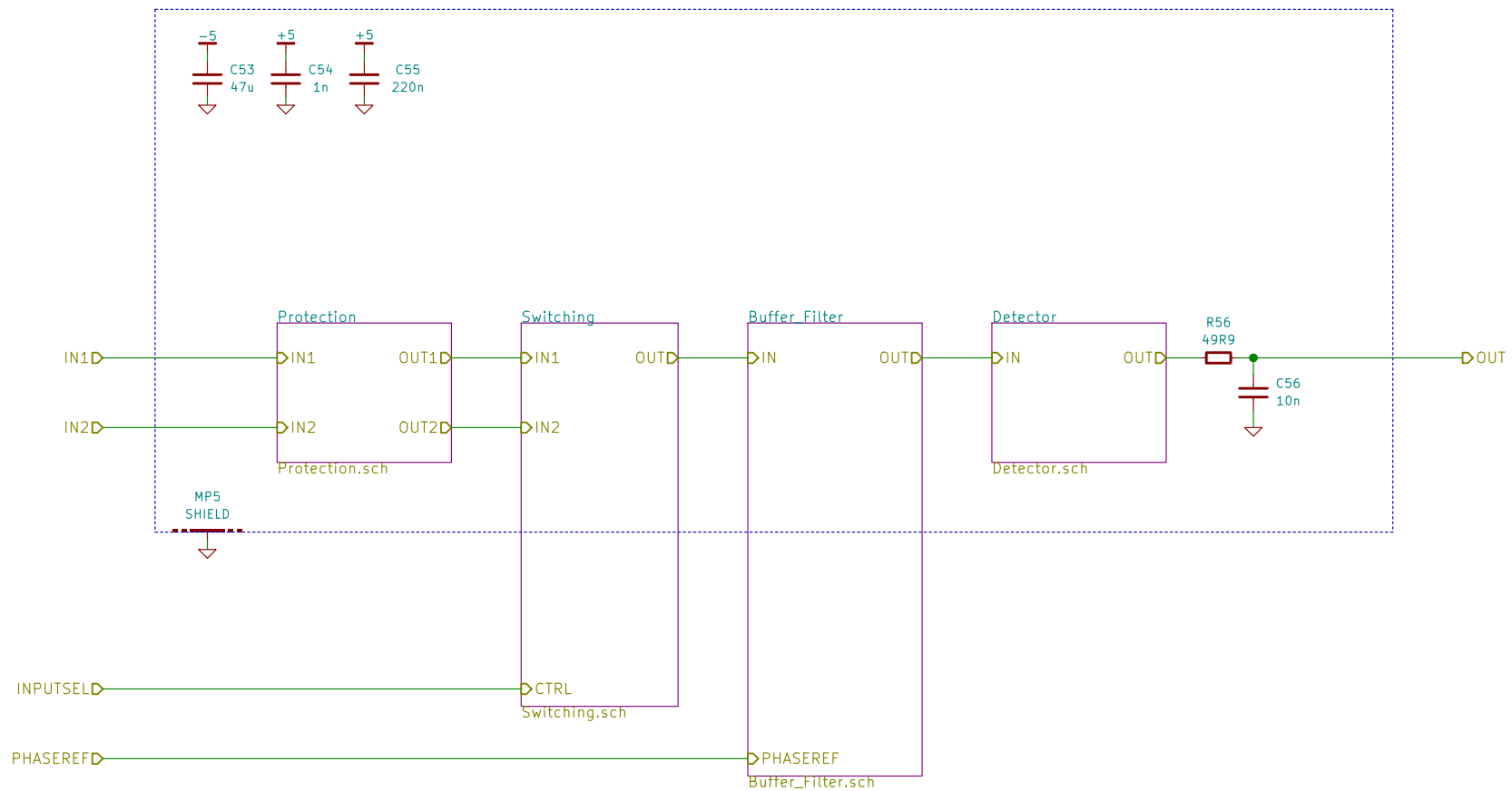
KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product

Rev:
Id: 2/13

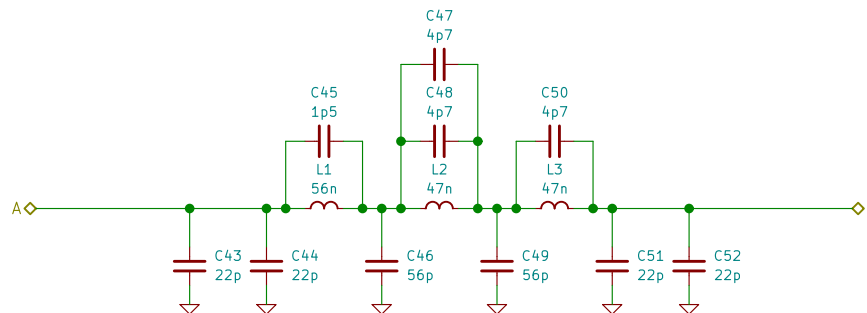




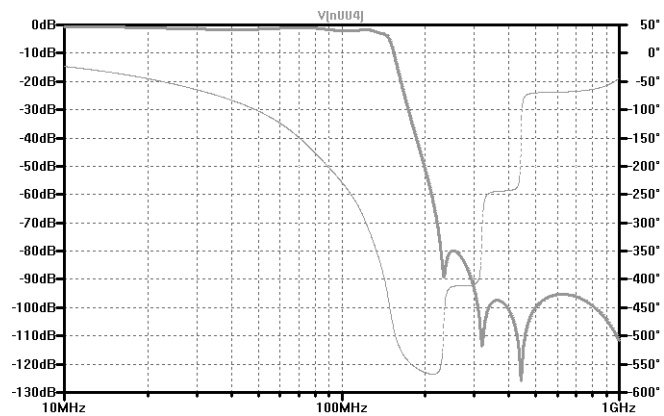
Eng: Chris Pavlina	
Gain/Phase Analyzer	
WCP52	
Sheet: /InputFrontend/Detector/	
File: Detector.sch	
Title: Logarithmic Detector	
Size: USLetter	Date: 2015-03-13
KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product	
Rev:	
Id: 10/13	



Eng: Chris Pavlina	
Gain/Phase Analyzer	
WCP52	
Sheet: /InputFrontend/	
File: InputFrontend.sch	
Title: Input Frontend	
Size: USLetter	Date: 2015-03-13
KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product	
Rev: 6/13	



Intended frequency response of filter:



Eng: Chris Pavlina

Gain/Phase Analyzer

WCP52

Sheet: /OutputAmp/LPF/

File: LPF.sch

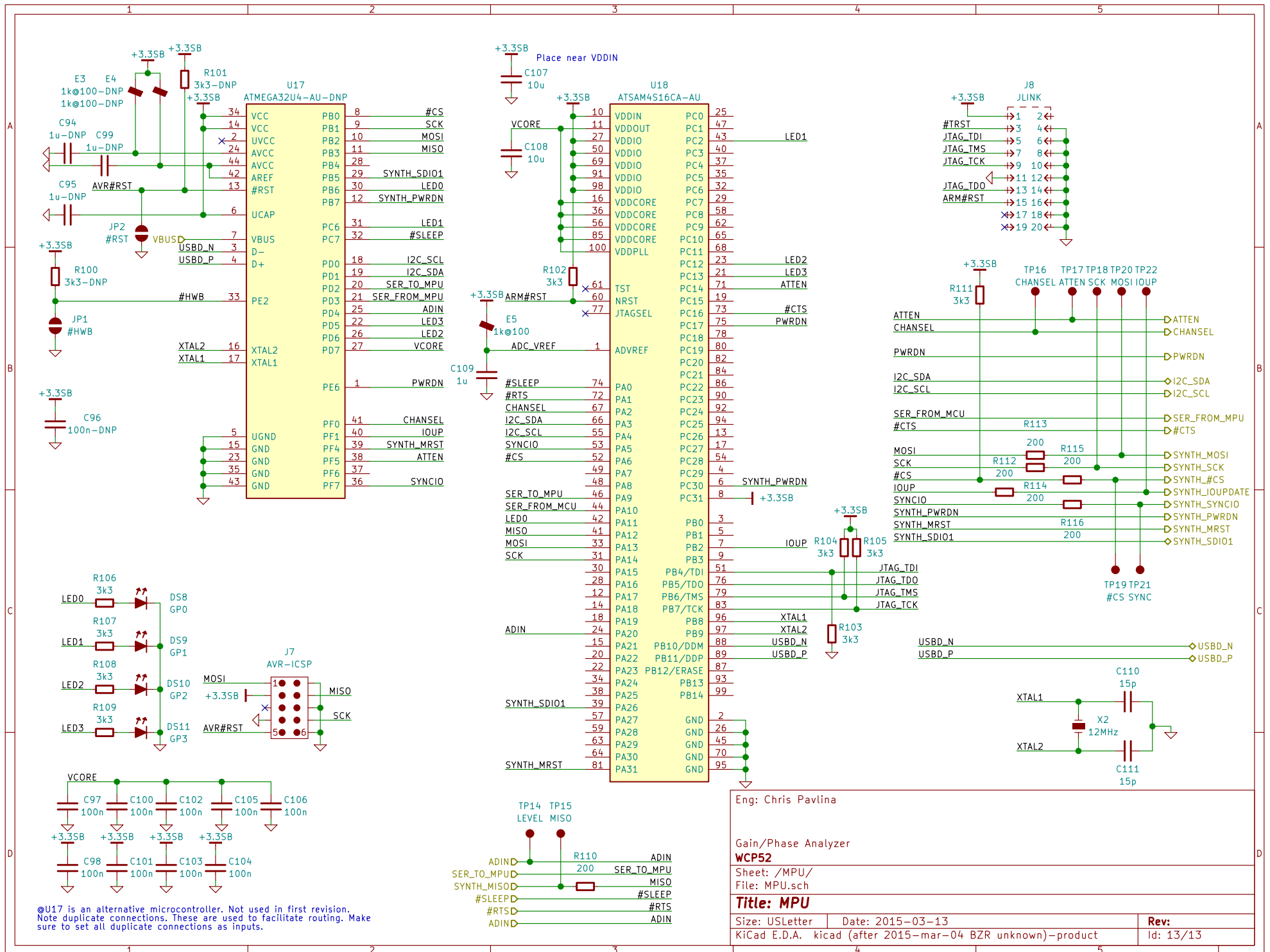
Title: LPF for Output Amplifier

Size: USLetter Date: 2015-03-13

KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product

Rev:

Id: 5/13



Eng: Chris Pavlina

Gain/Phase Analyzer

WCP52

Sheet: /MPU/

File: MPU.sch

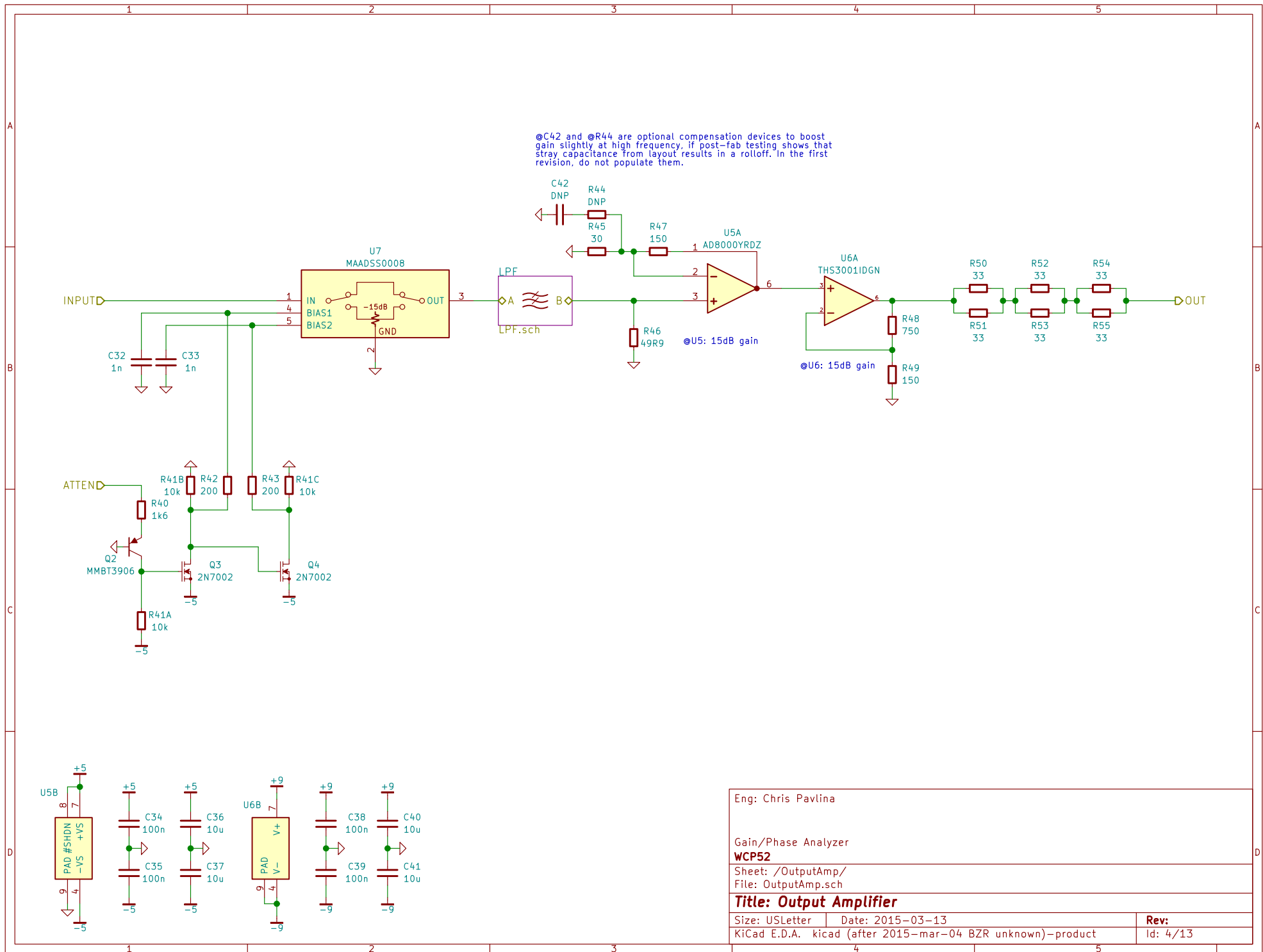
Title: MPU

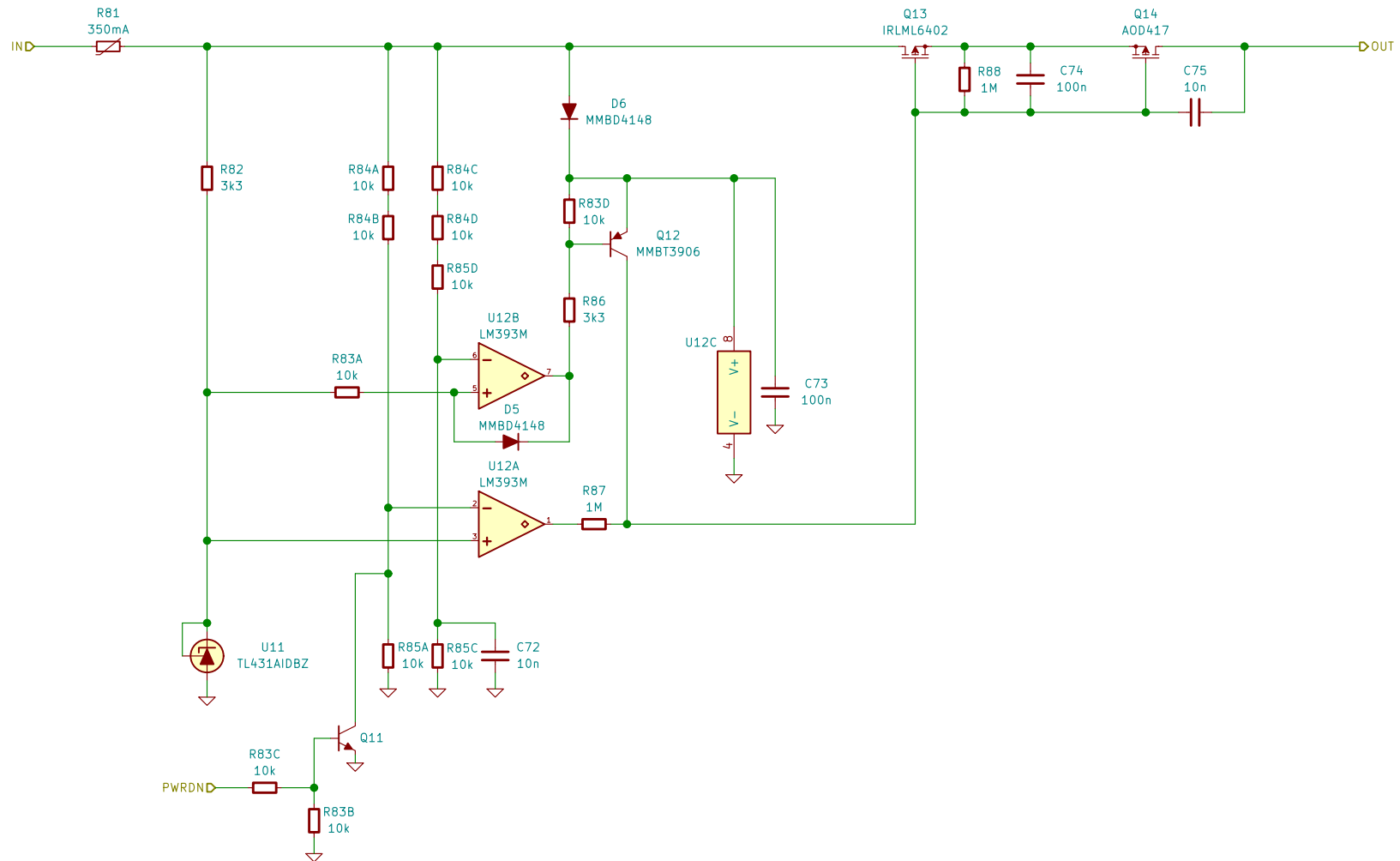
Size: USLetter Date: 2015-03-13

KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product

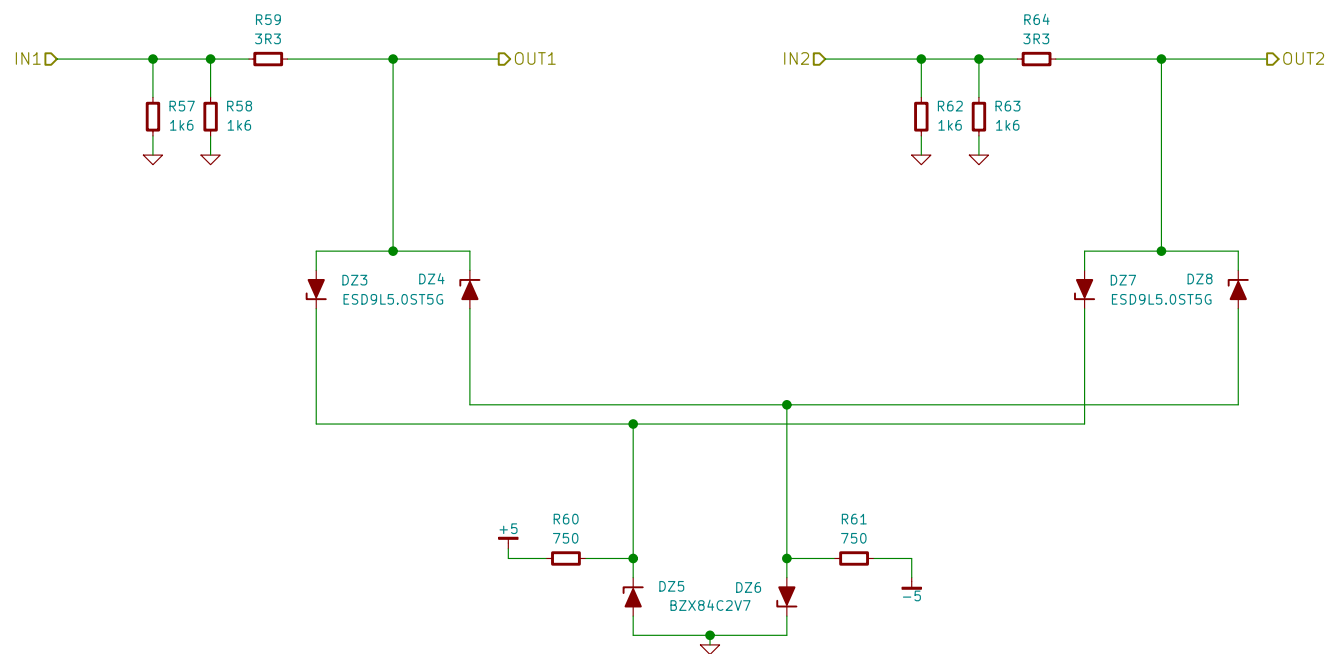
Rev:

Id: 13/13





Eng: Chris Pavlina	
Gain/Phase Analyzer	
WCP52	
Sheet: /PowerInput/ File: PowerInput.sch	
Title: Power Input Circuit	
Size: USLetter	Date: 2015-03-13
KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product	
Rev: Id: 11/13	



Eng: Chris Pavlina

Gain/Phase Analyzer

WCP52

Sheet: /InputFrontend/Protection/

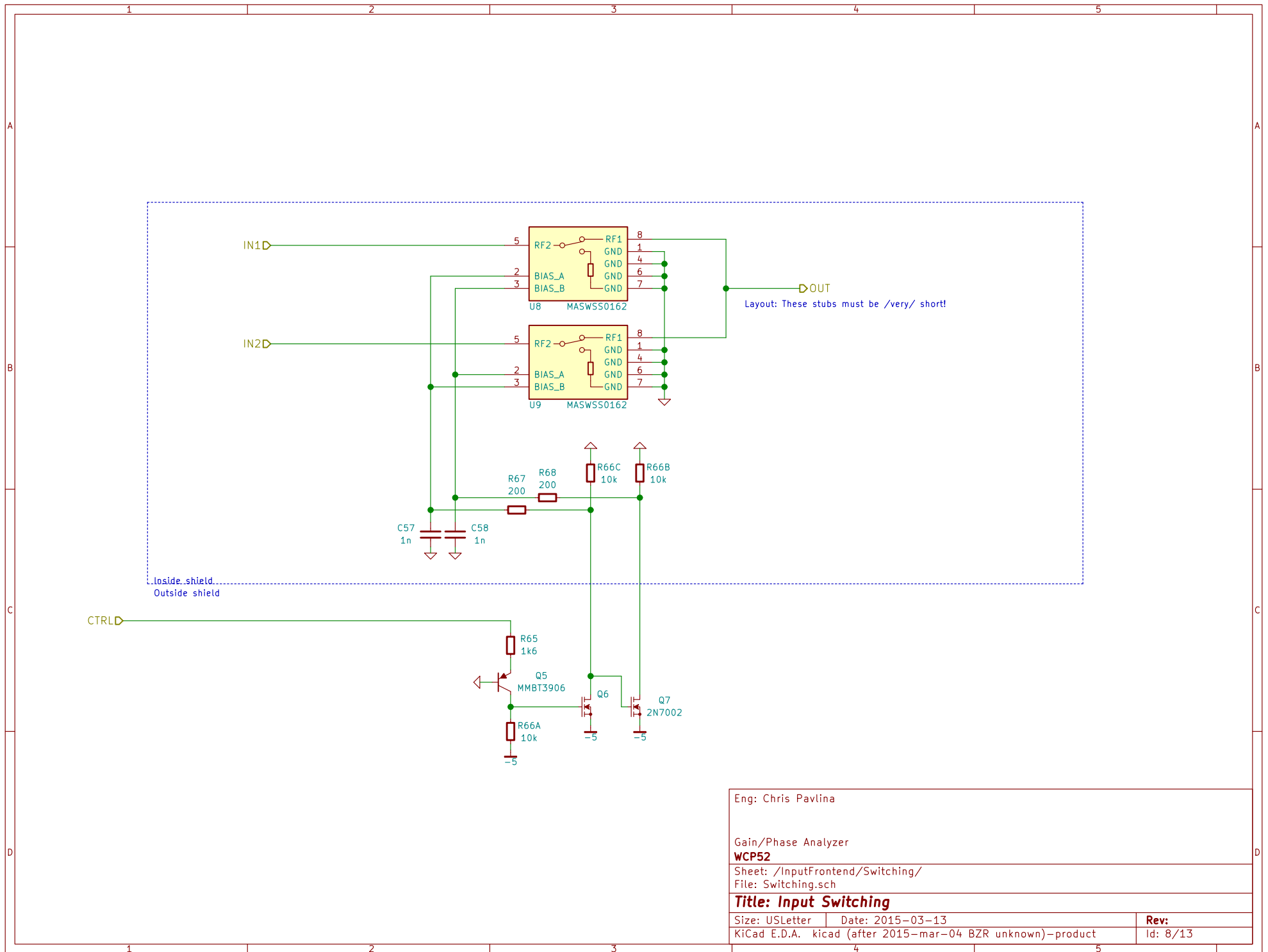
File: Protection.sch

Title: Input Protection

Size: USLetter Date: 2015-03-13

KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product

Rev:
Id: 7/13



Eng: Chris Pavlina

Gain/Phase Analyzer

WCP52

Sheet: /InputFrontend/Switching/
File: Switching.sch

Title: Input Switching

Size: USLetter Date: 2015-03-13

KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product

Rev:
Id: 8/13

References

- [1] Alpha & Omega Semiconductor, “AOD417 P-Channel Enhancement Mode Field Effect Transistor,” AOD417 datasheet, 2008. <http://aosmd.com/pdfs/datasheet/AOD417.pdf>
- [2] S. W. Amos and M. James, “Sawtooth generators,” in *Principles of Transistor Circuits*, 9th ed. Oxford: Newnes, 2003, ch. 14, pp. 281–292.
- [3] Diodes Incorporated, “Low Dropout Linear Regulator,” AZ1117C datasheet, October 2014 [Revision 3–2]. <http://www.diodes.com/datasheets/AZ1117C.pdf>
- [4] P. Horowitz and W. Hill, “Voltage regulators and power circuits,” in *The Art of Electronics*, 2nd ed. Cambridge: Cambridge, 1989, ch. 6, pp. 307–389.
- [5] Microchip Technology, “Low Quiescent Current LDO,” MCP1700 datasheet, October 2013 [Revision C]. <http://ww1.microchip.com/downloads/en/DeviceDoc/20001826C.pdf>
- [6] ON Semiconductor, “500 mA Negative Voltage Regulators,” MC79M00 series datasheet, July 2013 [Revision 15]. http://www.onsemi.com/pub_link/Collateral/MC79M00-D.PDF.
- [7] STMicroelectronics, “Precision 500 mA regulators,” L78M datasheet, June 2014 [Revision 20]. <http://www.st.com/web/en/resource/technical/document/datasheet/CD00000447.pdf>
- [8] Texas Instruments, “TL43xx Precision Programmable Reference,” TL431 datasheet, Aug. 2004 [Revised Jan. 2015]. <http://www.ti.com/lit/ds/symlink/tl431.pdf>
- [9] J. Tucker, “Using a buck converter in an inverting buck-boost topology,” *Analog Applications Journal*, Texas Instruments, fourth quarter 2007, pp. 16–19. <http://www.ti.com/lit/an/slyt286/slyt286.pdf>