Analog Discovery 2™ Reference Manual

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This manual applies to the Analog Discovery 2 rev. C

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Overview

ff jiɹff B b i ɹ ff ᵇ ff ff sfff ɹ n ɹ ɹ B b i ff ɹff ɹ b ɹ ɹ ɹ ff b b ff ffb ff ɹ b ɹᵍff i ff ff b ff b ɹᵃff jiɹb ɹ ɹ b ɹ ff B b i ɹ ff ᵇ ɹ b ff i ɹ ɹ ᵇ st ff st ff ff i ffstb ffb b b ff ɹst ff st ɹ ɹ i ff i ɹ ffff ɹ i ff ᵇɹ b ff ff ɹ ff ɹb ff ffff ɹ b b i b jiɹb ɹ ɹ ɹ ɹ b ᵇ b ᵇ ff ɹ ff ɹ ff b ffb b i b jiɹb ɹ st b st b ff ff ff b ɹ ɹ ɹ i ɹ sfff ɹff st ff b ff b ɹ ff ᵇ ff B b i ɹ ff ᵇ b ff ji ff b b ᵇ ff ff ff b b ɹ ɹ b ɹ ff ɹ ɹ ff

The Analog Discovery 2.

- b ff ɹ sfff ɹ ff ff jb ɹ b sfff ff ᵍ b ɹ ɹ ff B b i ɹ ff ᵇ B bsfff b
- b ff b ɹ b ᵇ ɹ i ff ff b ɹ b sfff ff ᵍ b ɹ ɹ ffB b i ɹ ff ᵇ B bsfff b
- ff ff b ɹ b sfɹff ɹ ff ffᵃ ff b ffb st ff sfffb ff ɹ ffsfɹb ff B ji b
- b ff sfb ff i ff ff b b sfff ff ɹ ɹɹ
- b ff ɹ b jiɹb K ɹ ɹ i ɹ ff b O sfff ff iɹ bɹ ɹ i bsfsfɹb ɹ ɹɹɹ iv
- b ff jiɹb iɹ b bᵇᵍff b sfff ff ɹ
- ɹ sf st jiɹb jiiff ji b ɹ ɹ i ɹsfffɹ ff ɹɹ
- sf i b b ff sf ff sfsfɹff ff bᵃɹ b bɹb ff sf ff b st ff ffsfff ffB b i ɹ ff ᵇ st ff ɹ i ɹ ff
- bᵃ ffb sfsfᵇ b ff st ff ff i
- B bᵃ bᵃ ffb sfsfᵇ ff ɹ i b ffᵃ ff b b st ff sfsfᵇ
- ɹ i ff b ff ff ff B
- ff b b ᵇᵍff ff ᵇ ɹ ɹ b ff jbi b b ɹ ɹ b i ff ᵍ ᵍ
- sfff B bᵇᵍff st ff sfff b sfff b ffb ff ff ɹ ff ff
- jiɹb B bᵇᵍff TK K B Tb b ff

ffB b i ɹ ff ᵇ b ff ji ff ff ɹ ᵇsfɹb ɹ ff ɹᵇ b ff ɹ ɹ b ff ff ɹ b ff K ffb ff b sfff ɹɹ b ɹ b ff b ffb ɹɹ b ff ɹ ff ff sfff b ɹ i ffᵃ ff b st ff bɹ bɹ ɹ i ff b b st b ff b ff ff ɹ b ff ff ɹ b b ɹff ᵇ ff ɹ ff b b ff b ff ɹ ff ᵇ ffff b b b bɹ ff ff st ff ff ff b ɹ ff ɹ ɹ ff ffff ɹ i b ff ff ff ɹ ff ff st ff b ff i ɹ i ff ff ff b ɹ b ff ᵇ i ff ff b ff ff b ɹ b ɹ ff ɹ ɹ ɹ ff ff ɹ ff ffB b i ɹ ff ᵇ ɹ ɹ ɹ ff ɹ ff st ɹ ɹ i b ff ff ff b ɹ i ɹ ff ff ɹ b ɹ sfff b ɹ b b ff ff bɹ ff ff ɹst ɹ ff b b ff ffb ff b ɹ ɹ b ɹ K ɹ ɹ ff ff st ɹ ff ff i ɹ b ɹ ff b ff sfff ff st ɹ b ɹ ffB b i ɹ ff ᵇ b ff ff ji ji b ɹ st i b b ff sfb ɹ ff ff ji

B b i ɟ ff ᵇ ɟ ff ffª i ff ff b ɟ ff ff ᵇ st st b B b i ɟ ff ᵇ ff bɟ ɟ st ff ff b ff

- B ɟɟ ᵇ ffb ffª ff b st ff stst ᵇ b ff ff ᵇ ff ɟ ff ff st ff ff ff stst ɟff ff st ff ff ffB b i ɟ ff ᵇ ff ɟ ff ff ff b ff st ff b ffB b i ɟ ff ᵇ
- ff ff ff ɟ ff b ff ff ji b ɟ st ff ff ff ɟb ɟɟ ᵇ
- K st ff ji b ɟ ffb b stff b ff ff stff b b ff i ff ff b
- ff ff ff ɟ ff b ɟ ff stff b b ff i ff ff b

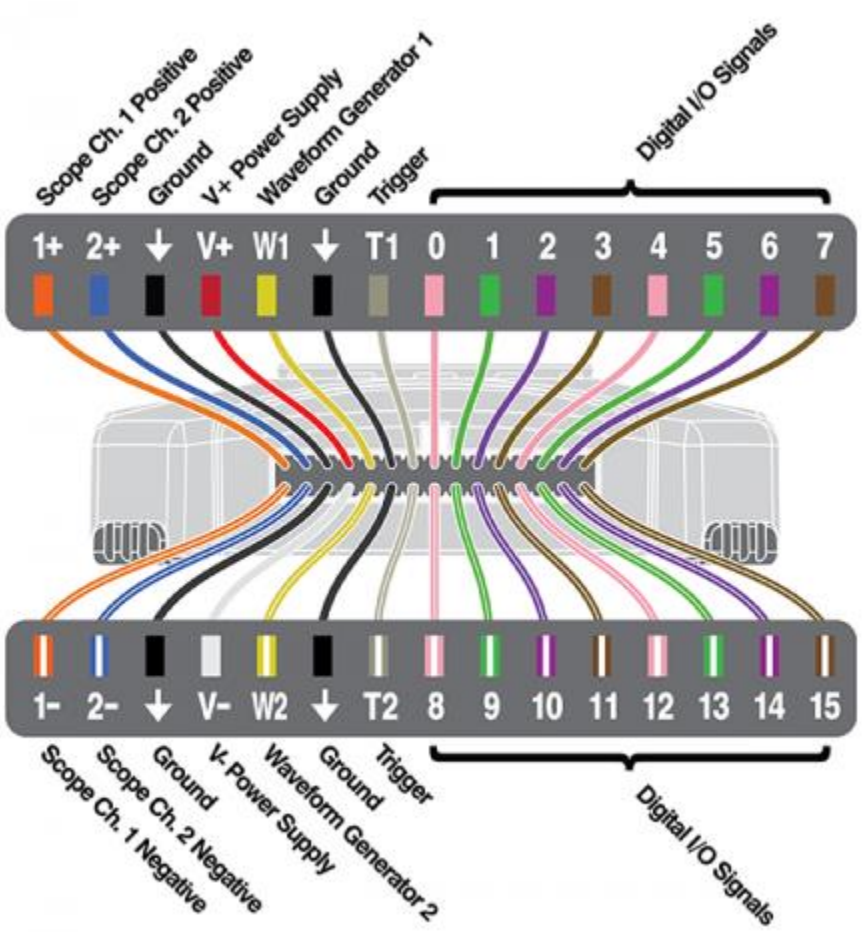

Figure 1. Analog Discovery 2 pinout diagram.

1 Architectural Overview and Block Diagram

B b i ɟ ff ᵇ ji ff ff ɟbi b ɟ st ff ff ff ɟ ji ff ff ff ffB b i ɟ ff ᵇ ɟ ff ɟɟ ª stb b T B stff ɟɟ b ᵇ ff O O ff ɟ ff ff b ff bstst ɟ b ɟ b b ɟ b ᵇ st i b ff ɟ ff ᵇ T B b b st ɟ b ji b ɟ ɟff ff ji ff ɟ st ff ff b ɟ ɟ ff b ffb ff ff ɟ ff ff st i b ff ff T B ɟ ɟ ff ff ɟ ff ᵇ ɟ b ff ɟ ff T b ff b ff bstst ɟ b ɟ ɟb b ff ɟ ff b ff b ff ɟ ff T B b ff ɟ b ffB b i ɟ ff ᵇ ɟ ɟ i ff ɟ i stb b ff ff b ɟɟ i b b b b ff ɟ i b ɟ i b b

ji b ɟ ff **Analog Input** b b ff ff **Scope** ff ɟ ffª ff ɟ ɟ b ff ffᵇ b ff ff b ff ff **Wavegen** ff ji b ɟ ff **Analog Output** b b ff **AWG** ff B ɟ ffª ff b ji b ɟ ff **Digital** ff b **D** ɟ ffª b ff ɟ ff ff ff ᵇ ff ɟ ff ᵇ b b ff ff ff ɟ ɟ ɟ ff ff ffff

ji b b ff b ɹ b ff ff bɹ b ɹ i ff ɹ B b i bi ff b ff St ff ɹª ff ɹ b bi ff b ɹª ff b ɹ ffª ff b ff ff ɹ b ɹ bᵇ Stff ɹᵇ ff b ɹ ɹ ff ji b Stb K B ff ɹ ɹ b ff ff ff b ff ɹ ff B ff ɹ ɹ b ff ff b ff b ɹ ɹ b ff ff ᵇ Stff ji b T ɹ ff ff ɹ i ff ɹbi b ɹ ji ff ff

- ff **Analog Inputs/Scope** ɹ ff ɹ ff
  - **Input Divider and Gain Control** ji b ɹ ɹ St b bStff ɹ ɹ ff ji i bɹ b ff ff ff ff ᵇ ff T B
  - **Buffer** ji ɹ Stff b ff ff
  - **Driver** St ɹ ff bStSt St jb ff ji b ff ff b St ff ɹ ffB ff bi ff ɹ b ff ff ɹ b St ɹ ɹ ff ɹ i
  - **Scope Reference and Offset** i ff ff b ff b ff ff ff ff ffb ff bi ff ff Stff bi ff
  - **ADC** ffb b i ji ɹ b ff ff Stff b ff
- ff **Arbitrary Outputs/AWG** ɹ ff ɹ ff
  - **DAC** ff ji ɹ b b b i ff ff B b ff
  - **I/V** ff ɹSt b bi ff ff ff
  - **Out** St bi ff
  - **Audio** b ɹ b St ɹ ɹ ff ffb St ff
- B St ff ɹ ɹ **Oscillator** b b **Clock Generator** St ɹ ff b ji b ɹᵇ ji b ffB b B ff ff
- ff **Digital I/O** ffª St ff St ff ff b ff ff T B Stj b ji ff ff ji ɹ b Tb ff ff ff b b O i ɹ B bᵇᵍ ff
- ff **Power Supplies and Control** i ff ff b ff b ɹ ff b StStᵇ bi ff b ff b ff StStᵇ St i b b ff bi ff ff b ɹ ff ff ɹ ff St ff St jb ff ff St ff ɹ StStɹ ff jb ff ff ɹ ff ffª ff b St ff StStᵇ ɹ ff ff b ff St ff ff ff ff StStɹ ff ff ff T B St ff ff ɹ b b ff ff
- ff **USB Controller** ɹ ff b ff ɹ ff T St i b ɹ i ff b ɹ ff T B ff ᵇ b ff St ff ff b ff ji b ɹ ɹ ff ff ff B ff b ɹ Stff ff b b b ff ff ffff ff T b T B
- ff **Calibration Memory** ff b b ɹ b ɹ Stb b ff ff ª ff St ff T ff b ɹ b ɹ ɹ ff ɹ ff Stff K St ɹ ɹ ff b bɹ ff ff B b i ɹ ff ᵇ ɹ ff b b i b ɹ b ɹ ɹ ɹ ᵇ K ffb b b ɹ b ɹ Stff b ɹ ɹ Stff ff b b b ɹ i ᵇ ff ff b Stb b ff ff b ff ff ɹ ff ᵇ ff b ff b ff ff ff ff St b b ff ff ff ff b ff ɹ ff ffb ɹ ff b b b ff i ff ff b ff ji b

K ff ff ɹ b ff b ɹ b ff ff St b b ff ᵇ ɹ ff ɹ b ffª b St ff ff Stff K St ɹ ɹ ff b bɹ ff ff ɹ ff b ɹ ɹ ᵇ b ff ɹ ff ff ff b ɹ b ff ɹ ɹ ff ɹ b K ffª ff b ff ɹ ff ff ff ff ff b B ffª b St ff ɹ ff b ɹ **(4)** ff ɹ ɹ ff bɹ ff ɹ ff ɹ ffª ɹ ᵇ ffª ɹ ff ff ff Stff ff b ff ɹ ffª ff b ff ff ff b ɹ bStStɹ ff b ff b K ff b ɹ **(3)** ff ᵇ Stff ɹ ffª ɹ b ɹ ɹ i ff b ff *mux* b *in* ff ff b ᵇ *P* St ɹ ɹ ff *N* ffi b ɹ ff *diff* ɹ ff ff jb b ff

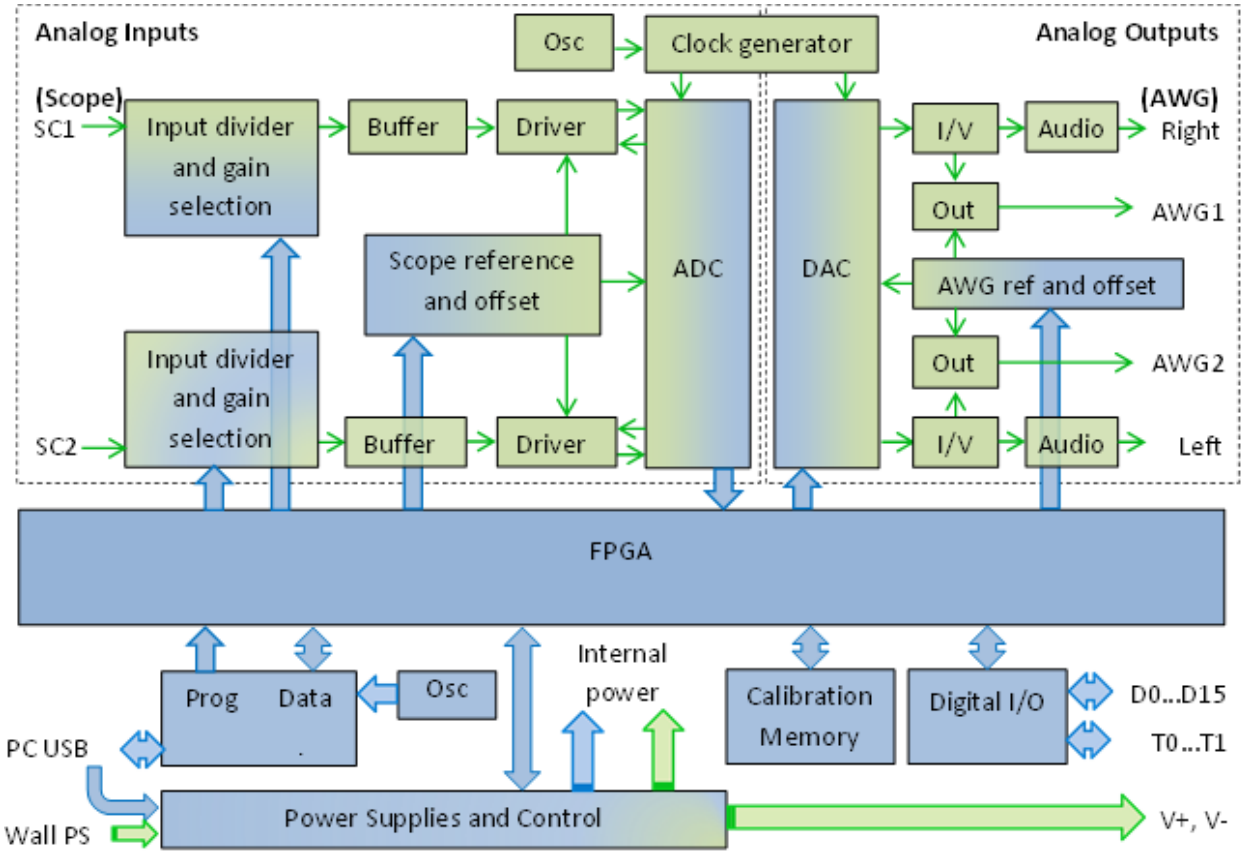

Figure 2. Analog Discovery 2 block diagram.

2 Scope

Unlike traditional inexpensive scopes, the Analog Discovery 2 inputs are fully differential. However, a GND connection to the circuit under test is needed to provide a stable common mode voltage. The Analog Discovery 2 GND reference is connected to the USB GND. Depending on the PC powering scheme, and other PC connections (Ethernet, audio, etc. – which might also be grounded) the Analog Discovery 2 GND reference might be connected to the whole GND system and ultimately to the power network protection (earth ground). The circuit under test might also be connected to earth or possibly floating. For safety reasons, it is the user's responsibility to understand the powering and grounding scheme and make sure that there is a common GND reference between the Analog Discovery 2 and the circuit under test, and that the common mode and differential voltages do not exceed the limits shown in equation (1). Furthermore, for distortion-free measurements, the common mode and differential voltages need to fit into the linear range shown in Figs. 12 and 13. For those applications which scope GND cannot be the USB ground, a USB isolation solution, such as what is described in ADI's CN-0160 can be used; however, this will limit things to USB full speed (12 Mbps), and will impact the update rate (screen refresh rates, not sample rates) of the Analog Discovery 2.

2.1 Scope Input Divider and Gain Selection

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- b J g
- st ffb

ff O bJ J

$$\frac{V_{mux}}{V_{in}} = \frac{R_6}{R_1 + R_4 + R_6} = 0.019 \quad (3)$$

ff O bJ J ff J st bi ff

$$|V_{in\,diff}| = |V_{in\,P} - V_{in\,N}| < 50V \quad (4)$$

ff ji bJ J

$$\frac{V_{mux}}{V_{in}} = \frac{R_4 + R_6}{R_1 + R_4 + R_6} = 0.212 \quad (5)$$

ff ji bJ J ff J st bi ff

$$|V_{in\,diff}| = |V_{in\,P} - V_{in\,N}| < 7V \quad (6)$$

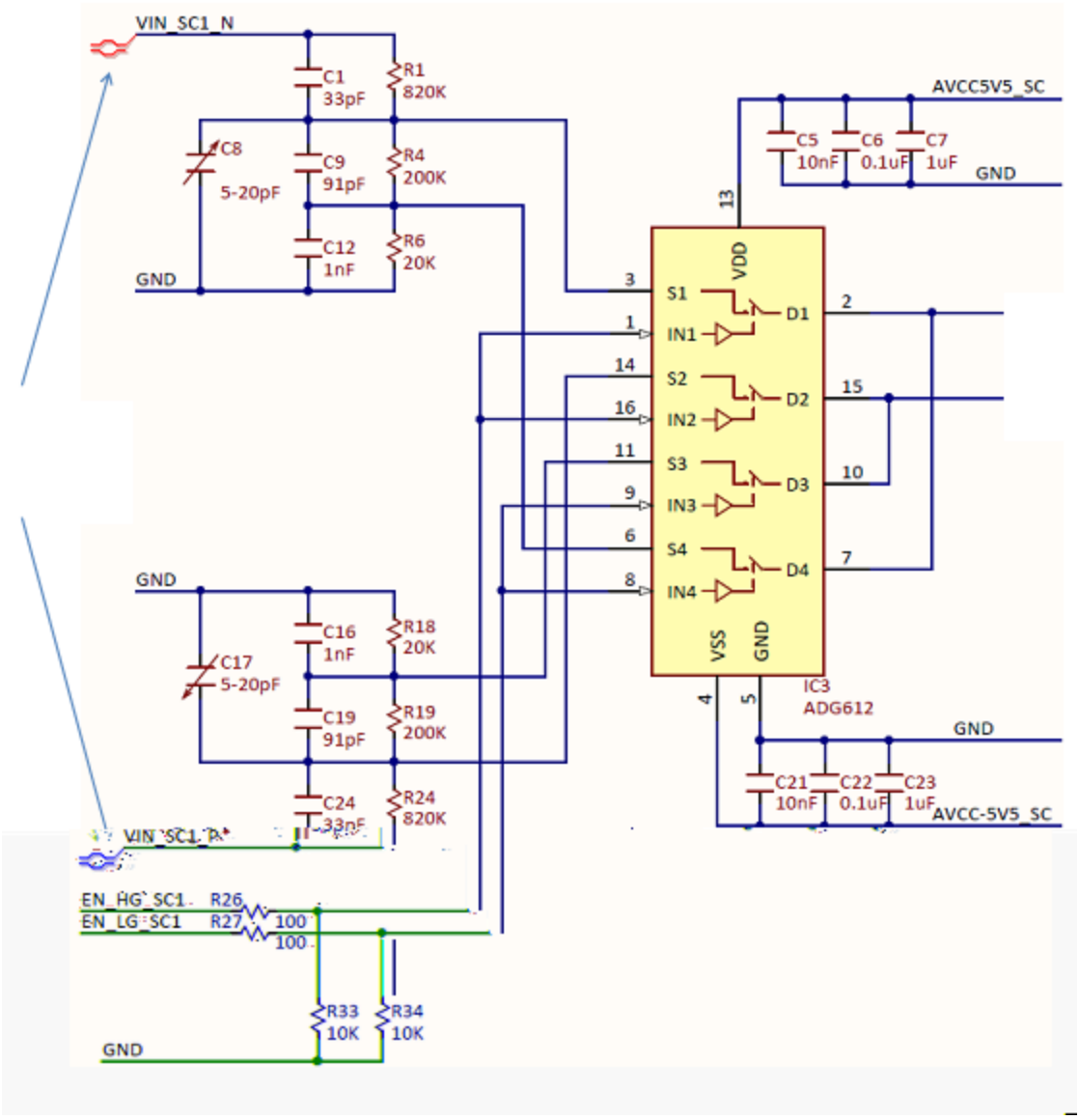

Figure 3. Input divider and gain selection.

2.2 Scope Buffer

B j ff j i SB St bi ff St j ff ff b ji j Stff b ffb b ff j St j j ff ji ff

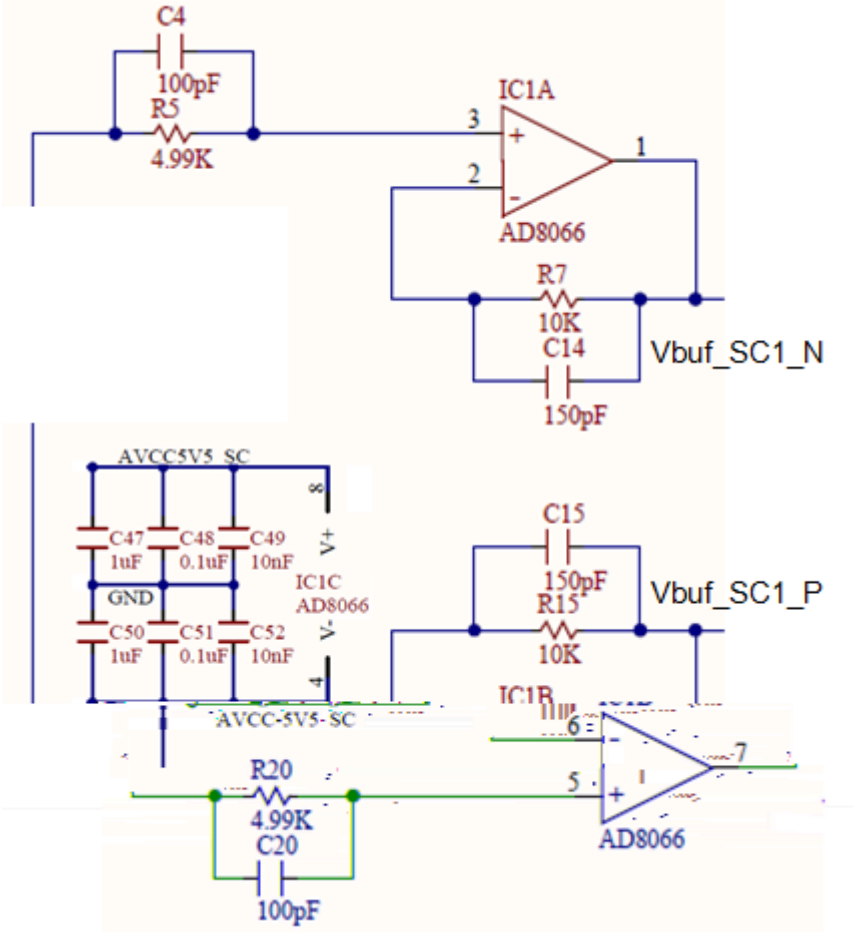

Figure 4. Scope buffer.

ff ff ffb ff ffB b ff

- j St b St j jff
- SB j St jb ff
- O
- ji Stffff g b j
- ff b ff
- O j ff g g B g g
- j ff StSt b bi ff b i ff
- bj bj St
- O ff bi ff b a j
- a ff ff j j Stff j j b j
- g
- O St ff B b St j jff b Stj b StSt b ff
- b Stb bi j i T

ff J b bStb J J ff ji ff ff St b[a] J j[g]ff ff b J b ff ff Stffb J i J ji ff ji J J b b J[b] i bJ

ffB J StStJff

ff b[a] J J St bi ff J i J $$-5.5V < V_{mux\,P}, V_{mux\,N} < 2.2V$$ (7)

ff b[a] J St bi ff J i J $$-5.38V < V_{buf\,P}, V_{buf\,N} < 5.4V$$ (8)

ff bJ J $$\frac{V_{buf}}{V_{mux}} = 1$$ (9)

2.3 Scope Reference and Offset

ji ff ff Stff bi ff ff ff ff ff ff b ff bi ff B J ff ff ff ff ff J ff i ff ff b ff ff ff ff ff bi ff b ff Stff bi ff ff ff b b ff ffStJ b ff ff ff ff ff bi ff b ff St J ff ff ff bi ff b J J J b [b] ffb Stff b ff J J j[g]ff b B b b ff B i ff ff b ff ff ff bi ff ffb ff ff ff J St ji b ff J b St J J ff b ff ff St J ff J Stff b ff

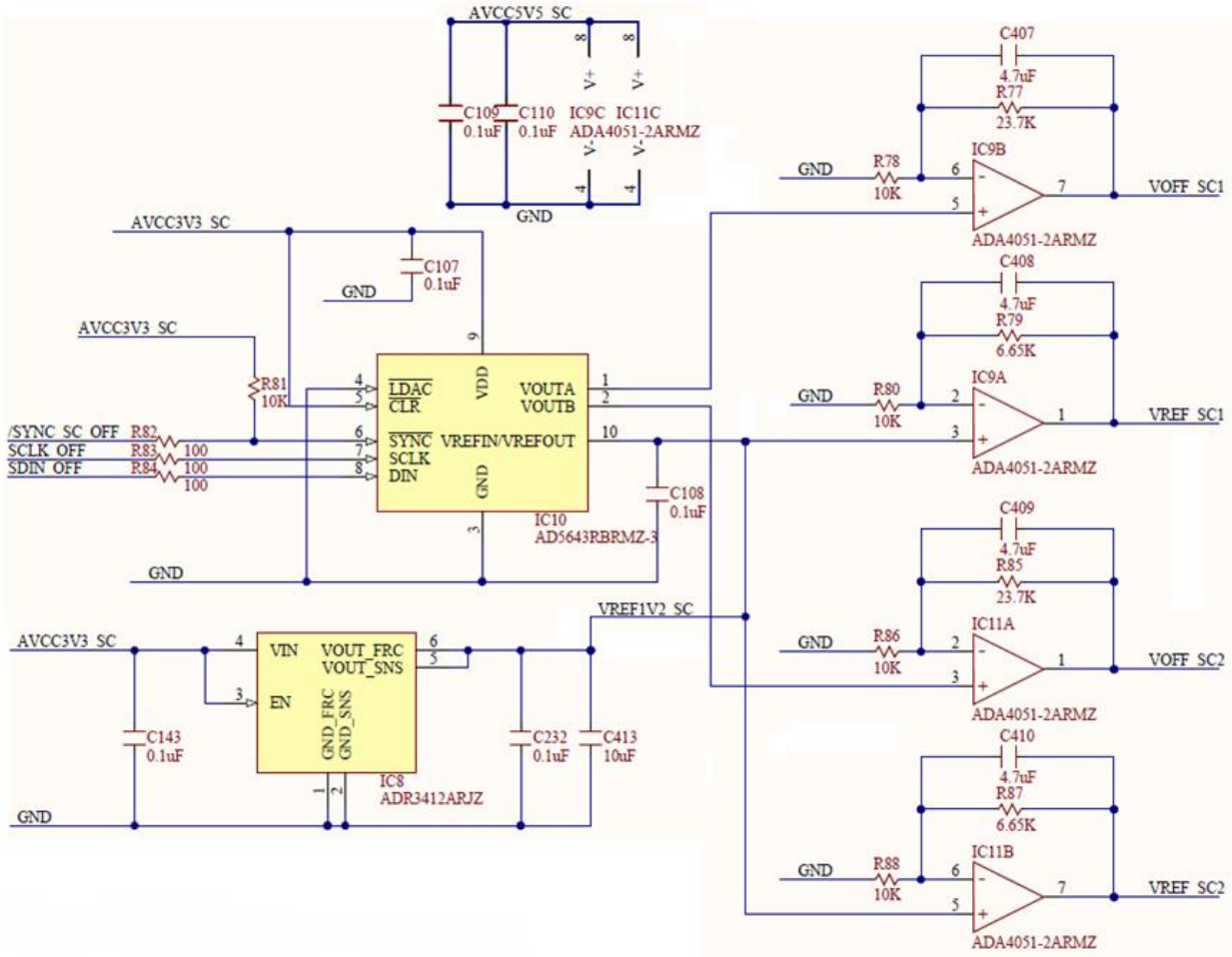

Figure 5. Scope reference and offset.

B B J St ff ji b b b bi ff ff ff ff ff

- K J Jb b b b bª J
- O ff Sffb ff ff J Jff SSt
- O Jff ff ff B bª J
- St J ff g g St Stb b Sj b

B b J b B

- O St ff b ff b b B
- St ff SSt b
- ff Jb J ff b ff St g

B B J St ff ff J bJ bJ J St St StB St

- ff b SSt b ff B b Sj b
- O ff bi ff bª J
- ff bi ff J
- ji T J J
- bJ bJ J St St
- J b i bJ b ff

ff ff ff ff ff bi ff i ff ff b ff ff Sffbi ff b ff

$$V_{ref\,SC} = V_{ref\,1V2} \cdot \left(1 + \frac{R_{79}}{R_{80}}\right) = 2V \quad (10)$$

ff ff bi ff ff Sffbi ff b ff

$$0 \le V_{off\,SC} = V_{out\,AD5643} \cdot \left(1 + \frac{R_{77}}{R_{78}}\right) < 4.044V \quad (11)$$

2.4 Scope Driver

B B B J ff ffb ff

- b ji b b J g
- ª ff ffb b J J J b g b g
- O J St bi ff J ff g
- bª J ff bi ff
- ff J i J ff
- bJ bJ St
- B n b ff St ff bi ff
- ffª J ff St ff SSt Jff O T
- b St ff B

K **Error! Reference source not found.** J ff

- J J i ff J ff ff Jb J St ffB J J Sffb ff St
- T J J i ff ff bi ff ffB
- B J i ff ff ff J b St J J ff Sffb J b b J b i ff J bb ffb ff ff b ff ffj ff St J J ff ffi b J ff

- B st ff j b b sty i ff st ji b T ff j j j st b j ffK j stStjff jff ffB j st b stSt ffK B b st ji b b b b sty i bi ff ff b j ff

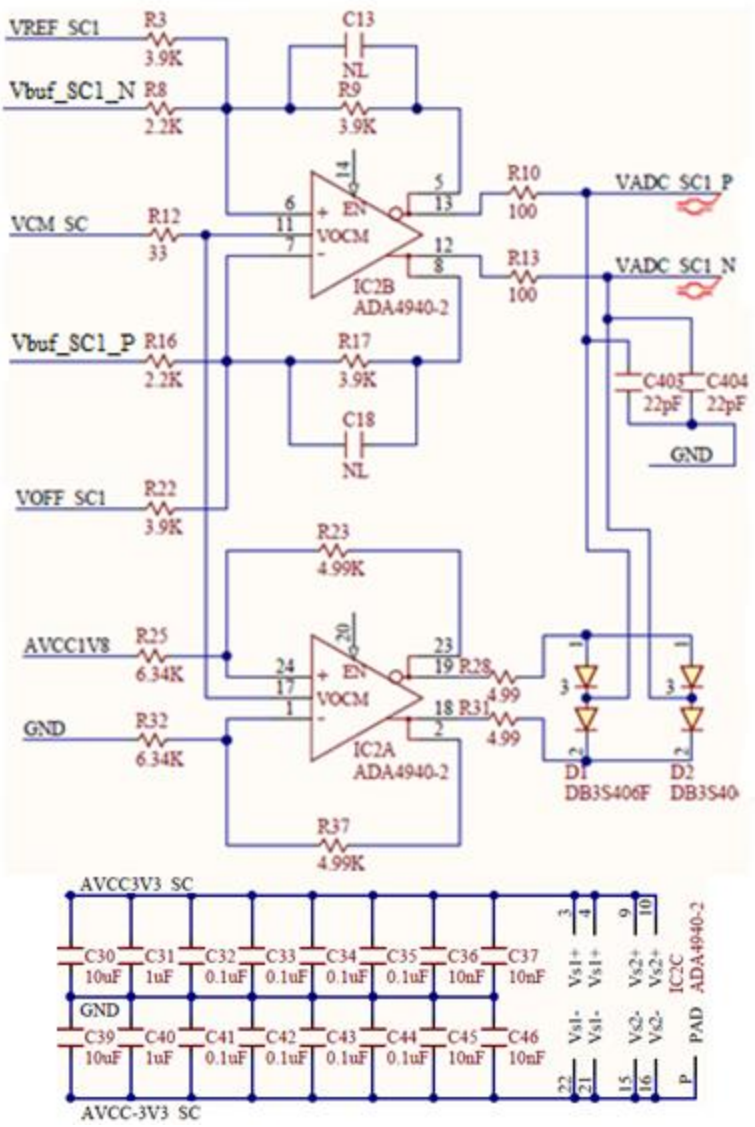

Figure 6. Scope driver.

B B j stStjff ff ff bi ff b i ff j

$$-3.5V < V_{+\,ADA4940} = V_{-\,ADA4940} < 2.1V \quad (12)$$

ff ji b bj j

$$\frac{V_{ADC\,diff}}{V_{buf\,diff}} = \frac{R_9}{R_8} = \frac{R_{17}}{R_{16}} = 1.77 \quad (13)$$

ff ff bj j

$$\frac{V_{ADC\,diff}}{V_{offSC} - V_{refSC}} = \frac{R_9}{R_3} = \frac{R_{17}}{R_{22}} = 1 \quad (14)$$

ff ff bj j

$$\frac{V_{CM}}{\frac{V_{ADC\,P} + V_{ADC\,N}}{2}} = 1 \quad (15)$$

ff b sty i bi ff b ff

$$V_{Out-IC2A} = V_{CM} - \frac{AVCC1V8}{2} \cdot \frac{R_{23}}{R_{25}} = 0.9V - \frac{1.8V}{2} \cdot \frac{4.99K}{6.34K} = 0.2V \quad (16)$$

$$V_{Out+IC2A} = V_{CM} + \frac{AVCC1V8}{2} \cdot \frac{R_{23}}{R_{25}} = 0.9V + \frac{1.8V}{2} \cdot \frac{4.99K}{6.34K} = 1.6V \quad (17)$$

b st ff B ji b
ff st ff ff ff ff

$$-0.1V < V_{+ADA4940} = V_{-ADA4940} < 1.9V \quad (18)$$

2.5 Clock Generator

A st ff j j j b K i ff ff b ff b nj ff g ffff ji ff

ff B ff ff b TOO j K ffi b ff j ji ff i ff ff b j i b g j ff ff jb
ff B b b g j i ff ff ff ff B

B b i ff j ff B K j TOO b ff b ff ff ji j i ff i ff ff b ffff ji ff ff TOO j ff j
st j j g ff b ff ff b O st b j g b T b ff b i j j b j ff b ff
ff ff T b ffnj ff j i b j b j ff g g j

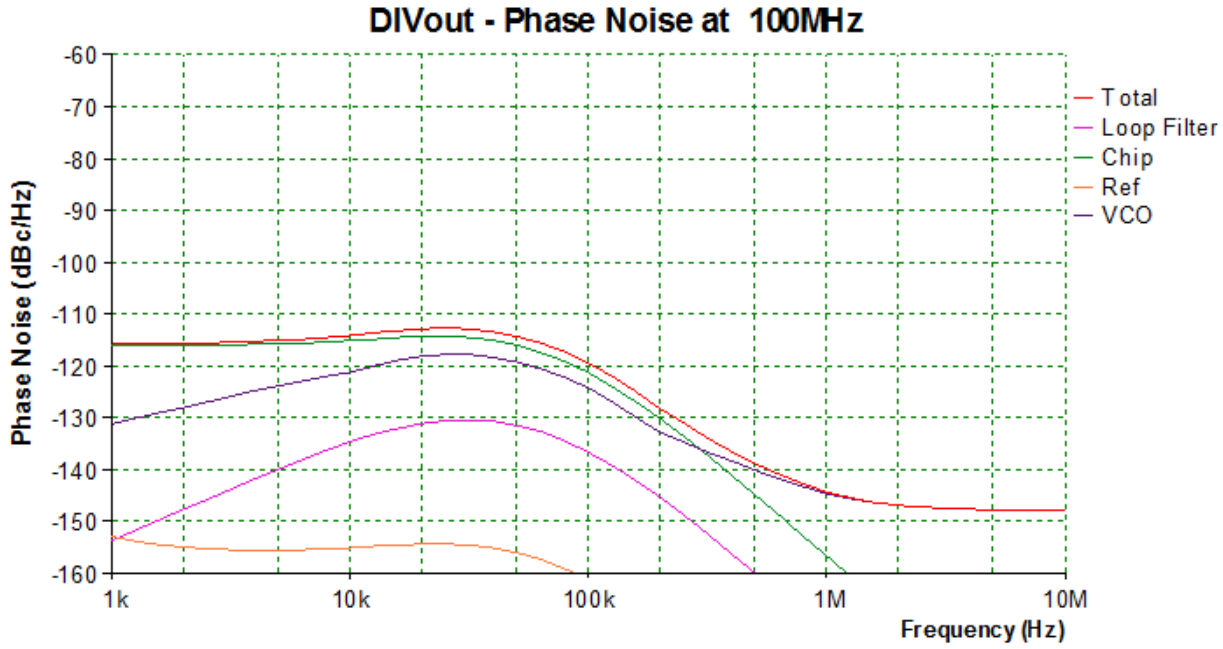

Figure 7. Phase noise figure for the clock generator.

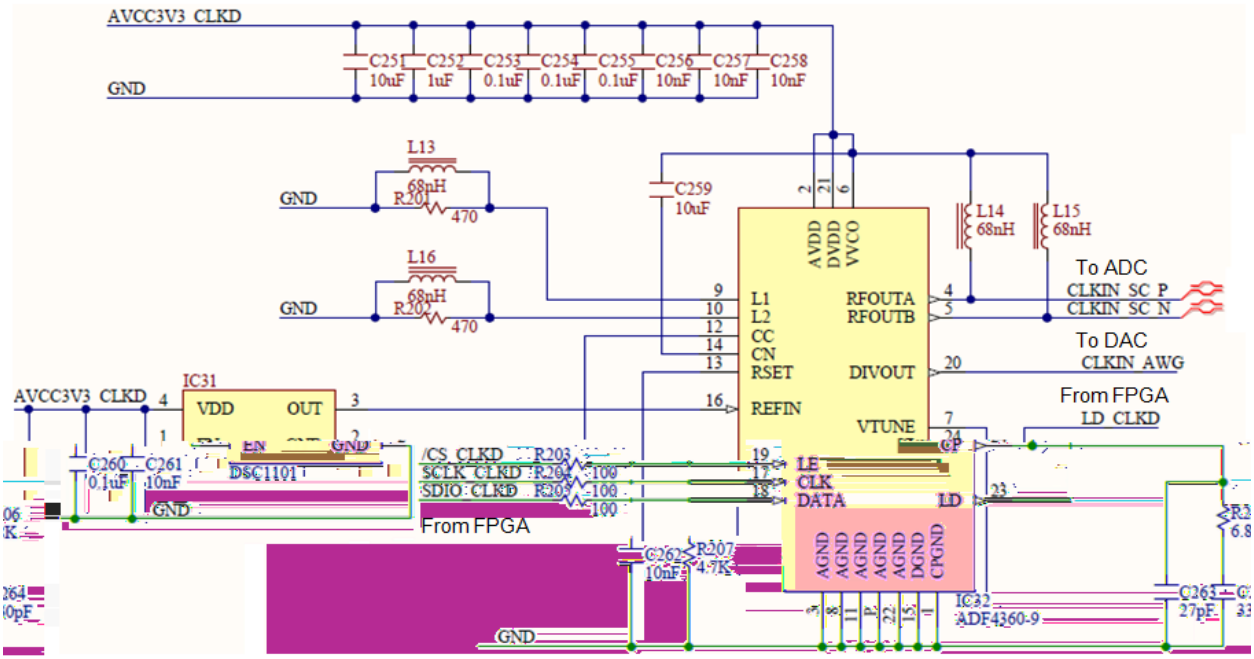

Figure 8. Clock generator.

2.6 Scope ADC

2.6.1 Analog Section

ffB b i j ff b ff b b b ff ji sffffff sf ff j T B B b i sfb ff B b j ji ff

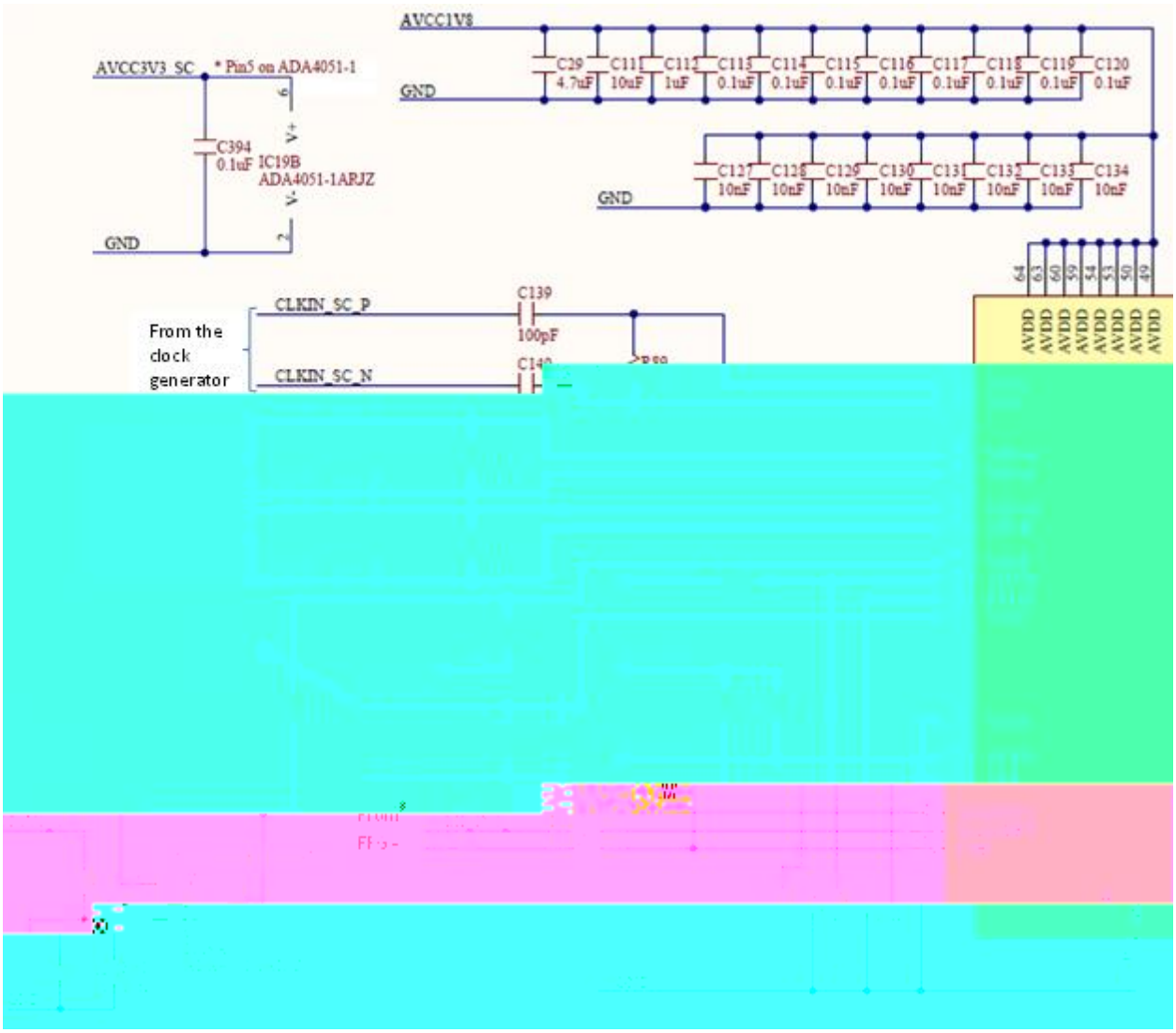

Figure 9. ADC - analog section.

ff ɹ ſt b ffb ff B

- g
- g
- O ſt ff b ff B ff T
- ɹ ff ff ɟb b b i ɹ ſt ɹ g b ɹ
- K b ſtɹ i ff ff ɟff g
- ɟſt bi ff ff ff ff ffb b ſtff b ɹ ɹ
- ſtſt ɹ ff ff ɟb b b i ɹ ſt
- O O
- ff ɟb ſt ſtɹ
- ff ɹ b b i b ff ſtff ff b b b
- ſtɹ b b b ff b ɹɟg ff
- K ffi ff ɹ ſt ɹ ɹ ff
- b b ſt ɟſtff ſtɹ
- ɹ ɹ ff ff b ff ɟi ɹ b ff ſtb ff i ff ff b ɹ
- ff i b b ɹ i ſt ff ff

- b b j st i b b ff b b b b ji ff

ff j ff ff jb j st b ff j ff jb b stb j ff st j ff i ff ff j i j ff ff bi ff ff j ff ff jb j B stff b ff j ff j j stff b ff b ff ff j j ff b b j j ff b stff b j i b b b g b st j i b ff B ff ff b ff ff ff ff bi ff j ff ff b K ff B i ff ff b ff ff ff ff ff ff bi ff ff ff j ff ff bi ff

ff j ff ff jb j st bi ff b i ff j $-1V < V_{ADC\,diff} < 1V$ **(19)**

2.6.2 Digital Section

ff ji j b bi ff ff B b ff ff st j i T B b b ff stst j ff b

j j j g ff ff ff ff T B st j b j st ff a ff ff j ff j ff ff b ff b j i ff b b O j st j ff ff T B b j g j i b b ffff ji ff

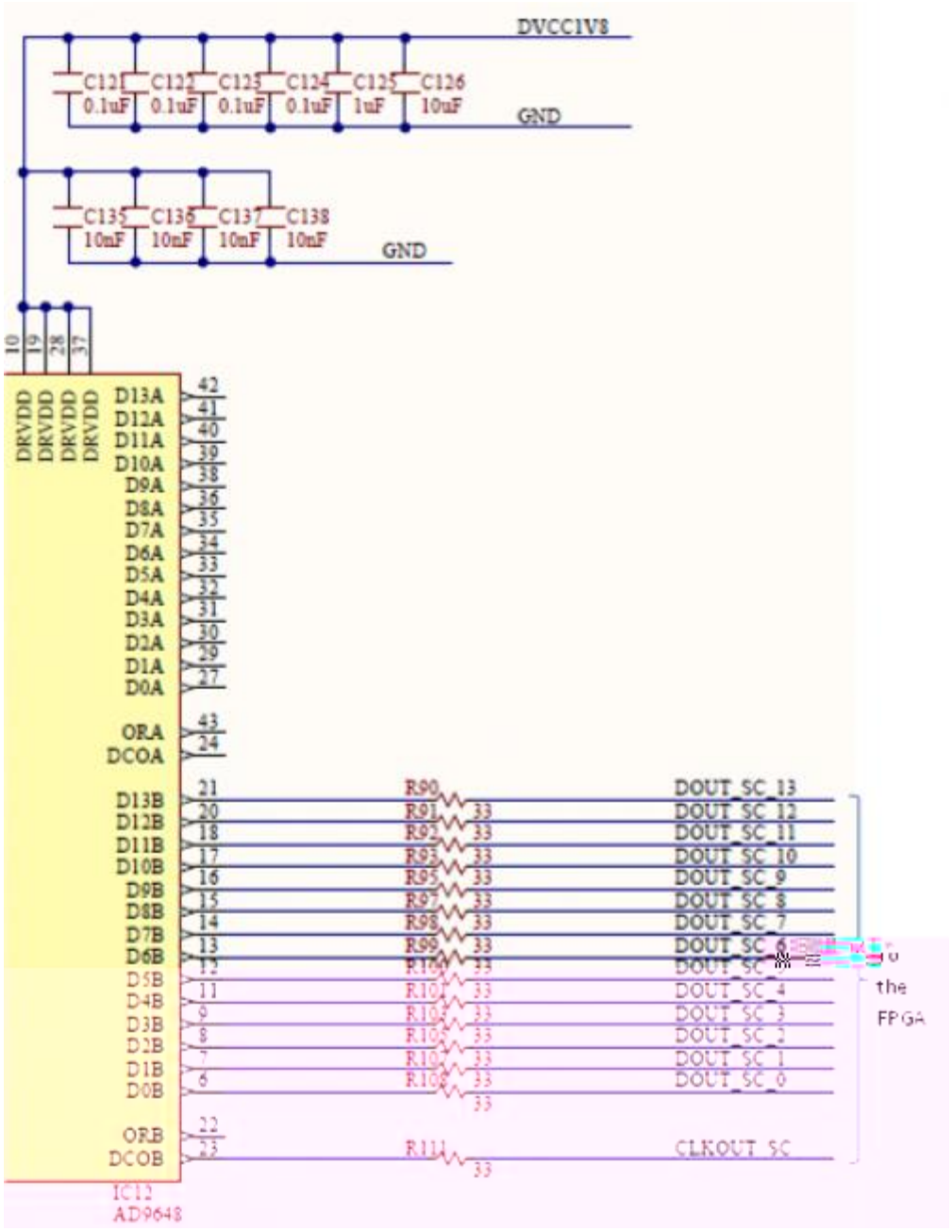

Figure 10. ADC - digital section.

2.7 Scope Signal Scaling

J J i bJ ff b J **(3) (5) (9) (13) (14)** b **(15)** St ff J bSt ff ff b Stffi bJ b ff

$$\boldsymbol{Low\ Gain} = \frac{\boldsymbol{V_{ADC\ diff}}}{\boldsymbol{V_{in\ diff}}} = \mathbf{0.034}$$

$$\boldsymbol{High\ Gain} = \frac{\boldsymbol{V_{ADC\ diff}}}{\boldsymbol{V_{in\ diff}}} = \mathbf{0.375} \qquad \textbf{(20)}$$

j j i ffB j st bi ff b i ff j (**19**) j V_{offsc} b ff j b i ff (**11**) stff ff j b st j j b ff j b i ffj

$$\textbf{\textit{at Low Gain}}: -\mathbf{30V} < \boldsymbol{V_{in\,diff}} < 28.\mathbf{6V}$$

$$\textbf{\textit{at High Gain}}: -\mathbf{2.7V} < \boldsymbol{V_{in\,diff}} < 2.6\boldsymbol{V} \quad \textbf{(21)}$$

ff st ff b ff ff b ff b b b ff b j b j b ff b i ff ff b ff stff j jff

$$\textbf{\textit{at Low Gain}}: -\mathbf{25V} < \boldsymbol{V_{in\,diff}} < 25\boldsymbol{V}$$

$$\textbf{\textit{at High Gain}}: -\mathbf{2.5V} < \boldsymbol{V_{in\,diff}} < 2.5\boldsymbol{V} \quad \textbf{(22)}$$

ffff ff ff ff ff ff j i stff ff j b st j j b ff b b ff **(10)** **(11)** b **(14)**

$$-\mathbf{2V} < V_{offSC} - \boldsymbol{V_{refSC}} < 2.\mathbf{044V} \quad \textbf{(23)}$$

ff ff j b st j j ff j i ff ff j b b ff j b b ff stff ffff ff b j ff ff j b ffff ff ff b $V_{off\,eq\,in}$ 8 â Ù Ù

$$\textbf{\textit{at Low Gain}}:$$

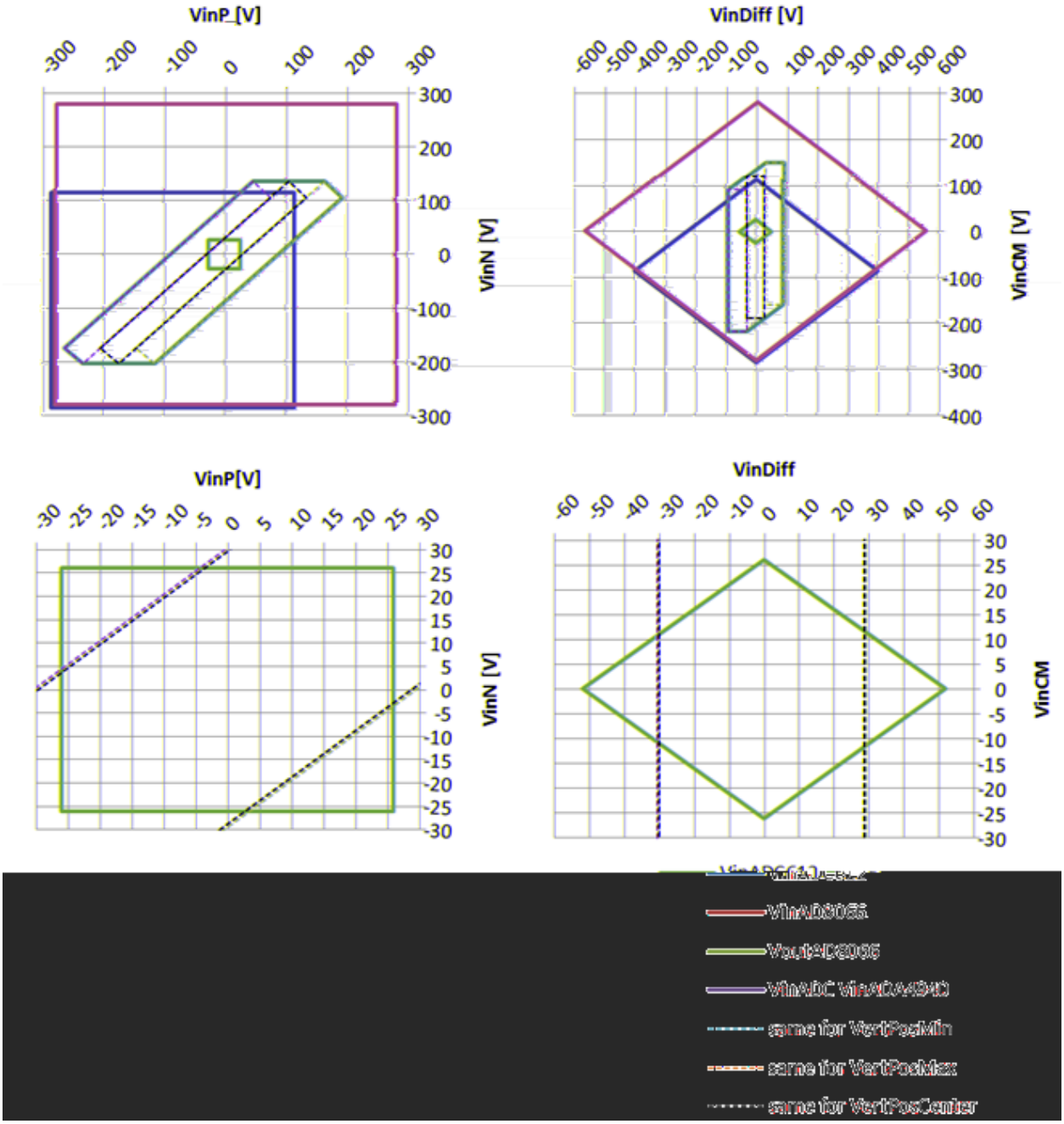

Figure 11. Scope input signal range.

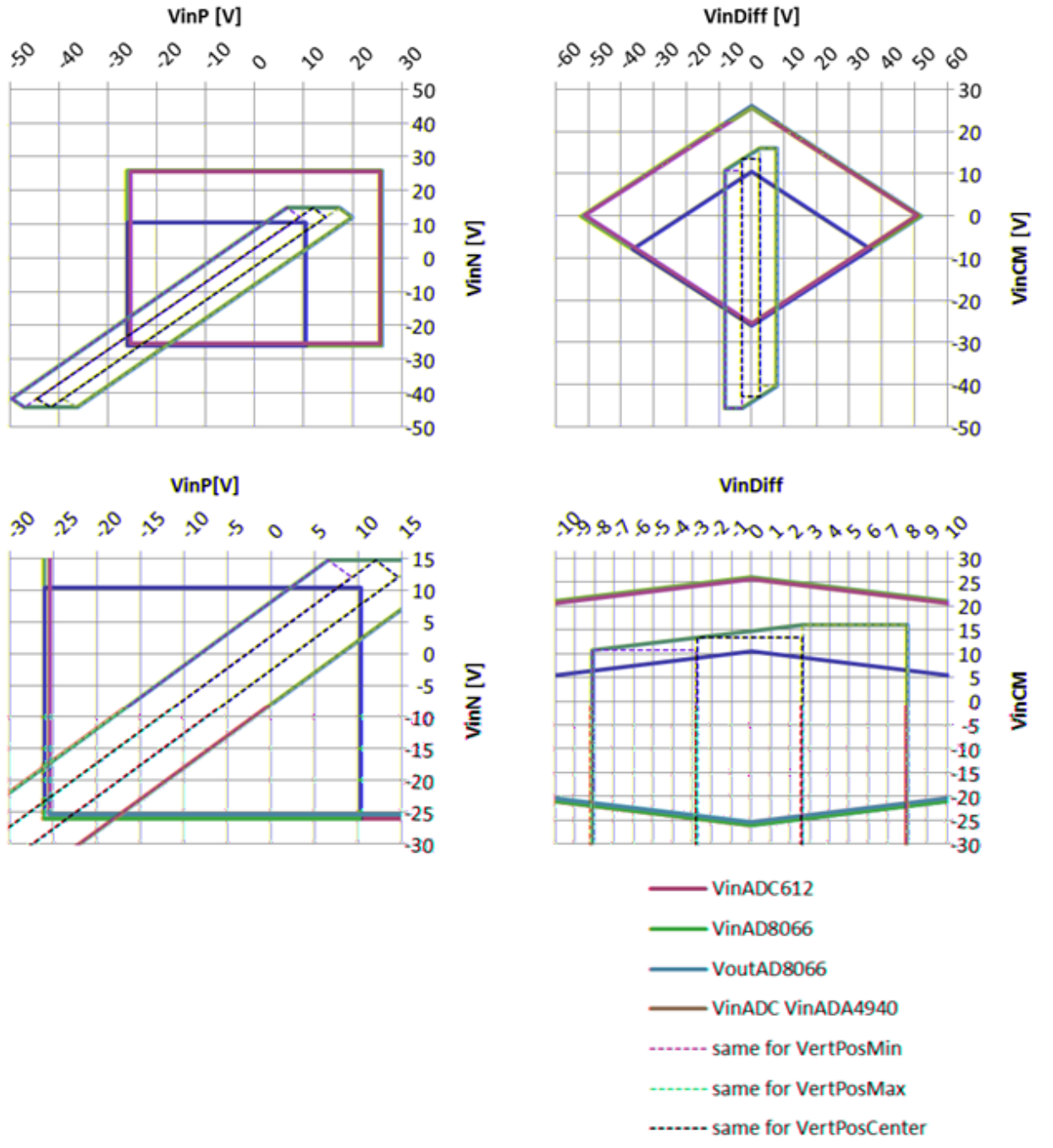

Figure 12. Scope input signal range.

ff b ff ff b i ff ffSt ff ff ff ɹ stbᵇ b ffb ff Sttff ffff ff ff b ff ffff b ff ff b i ff ɹ ffb jbi b ff ɹ ff ff ff St ff ff ɹ b St ɹ ɹ ff *VoffSc = 2.022V* ɹ ff b ɹ **(11)** ff ff ff ff ɹ stbᵇ b ffb ff ff ɹ b St ɹ ɹ ɹ ff bᵃ ɹ *VoffSc = 4.044V* b ff ji ff ff St ff ɹ ɹ ffi b ɹ ff ff ɹ b St ɹ ɹ *VoffSc = 0V* B ᵇ ɹ ff ff jb ff ff ɹ b St ɹ ɹ ɹ St ɹ ff ɹ i ff ɹ stbᵇ b ff b ffb ɹ b b ff ff b i ff b ᵇ ɹ ff ff jb ff St ɹ ɹ B ji b ɹ i ff i ɹ ff ff b ff ff b i ff ffª ffff ff ɹ stbᵇ b ff ɹ St bi ff b i ff b ɹ i ffB b b ff ffj ff b ᵍff b b ff ɹ ɹ ffSt ff ff ff ff Sttff ffff ɹ b ff ɹ ff b ɹ i ff ff

B ji b ffffSt j i ɹ ɹ ff b ff ff b i ff ɹ i b ᵇ ɹ ɹ ff ff ɹ ff ff ff ɹ b ɹ ɹ ɹ ff ff jb ff ɹ ɹ ɹ ff ji b stb ffff ff ffi ff ff ji ff ɹ ff ɹ ɹ ɹ i ff ji b ɹ b b ɹ i ff

B ff b ff b j b j b j j b j b b b ff ff j Sffj j ji b ffSt ff ff b j K j ff ff ff St j j j b ff b b b j j b j

O bj ji ff ff j Stff j j b b j ff j ffb b i ff j ffffSt St j j ffb ffi b j ff j St V_{inP}, V_{inN} j ff b i ff b b ff b j **( )**

ji bj ji ff b j j i ff b j **(7)** b **( )** St j j ffb ffi b j ff j St j b b j ff b i ff

$$-26V < V_{inP}, V_{inN} < 10V \quad \textbf{(25)}$$

B j j b b ff j ff ff jb j St ji b j ff j ffff j b ff ff bi ff ff j b St j j j j j ff b j j ff b i ff

$$-7.5V < V_{inDiff} < 7.5V \quad \textbf{(26)}$$

ff ff j ff ff ff ff ffff b Sj b Stb b ff ff b ff j ff ff b ff ji ff b ff b ff j b a b ff ff ff ff b j

ji ff b ffb Stff b ji b j ff ff b ff j St bi ff b j b i ff ffb ffb i ffb j ff j ff ff ff ff ff j ff ji b ff j ff ff jb j St bi ff j b StSt jb i ff St b St ff ff ff j St bi ff j ff ff j b St j j ff Sffj ff b ji i bj j ff ff ff ff b ff j ff b j ff j b ji b ffa ffSt ff ff j St bi ff j

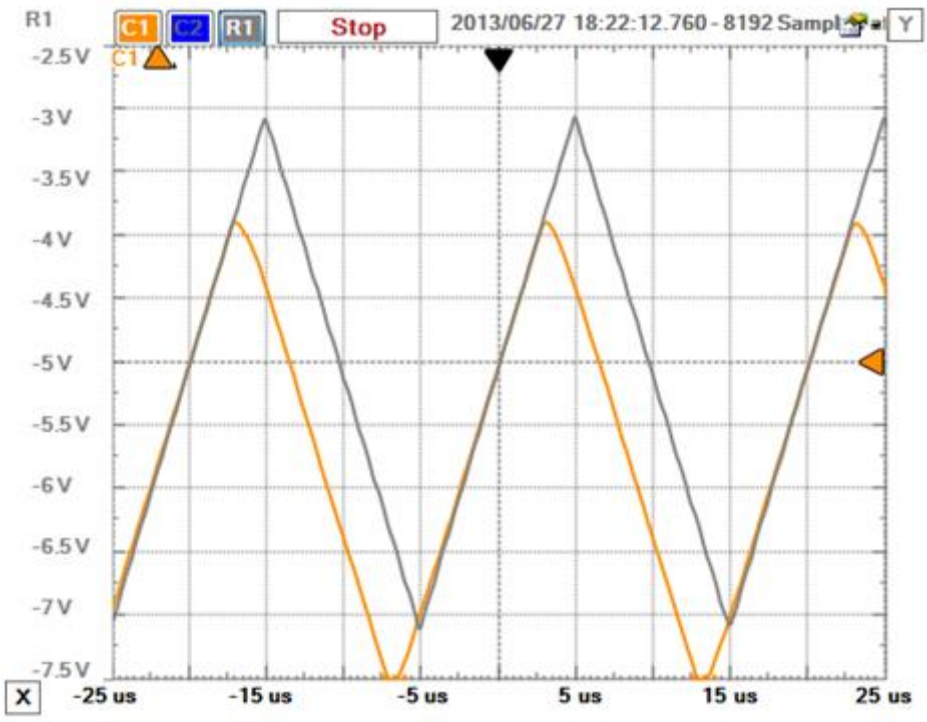

Figure 13. Common mode input voltage limitation.

2.8 Scope Spectral Characteristics

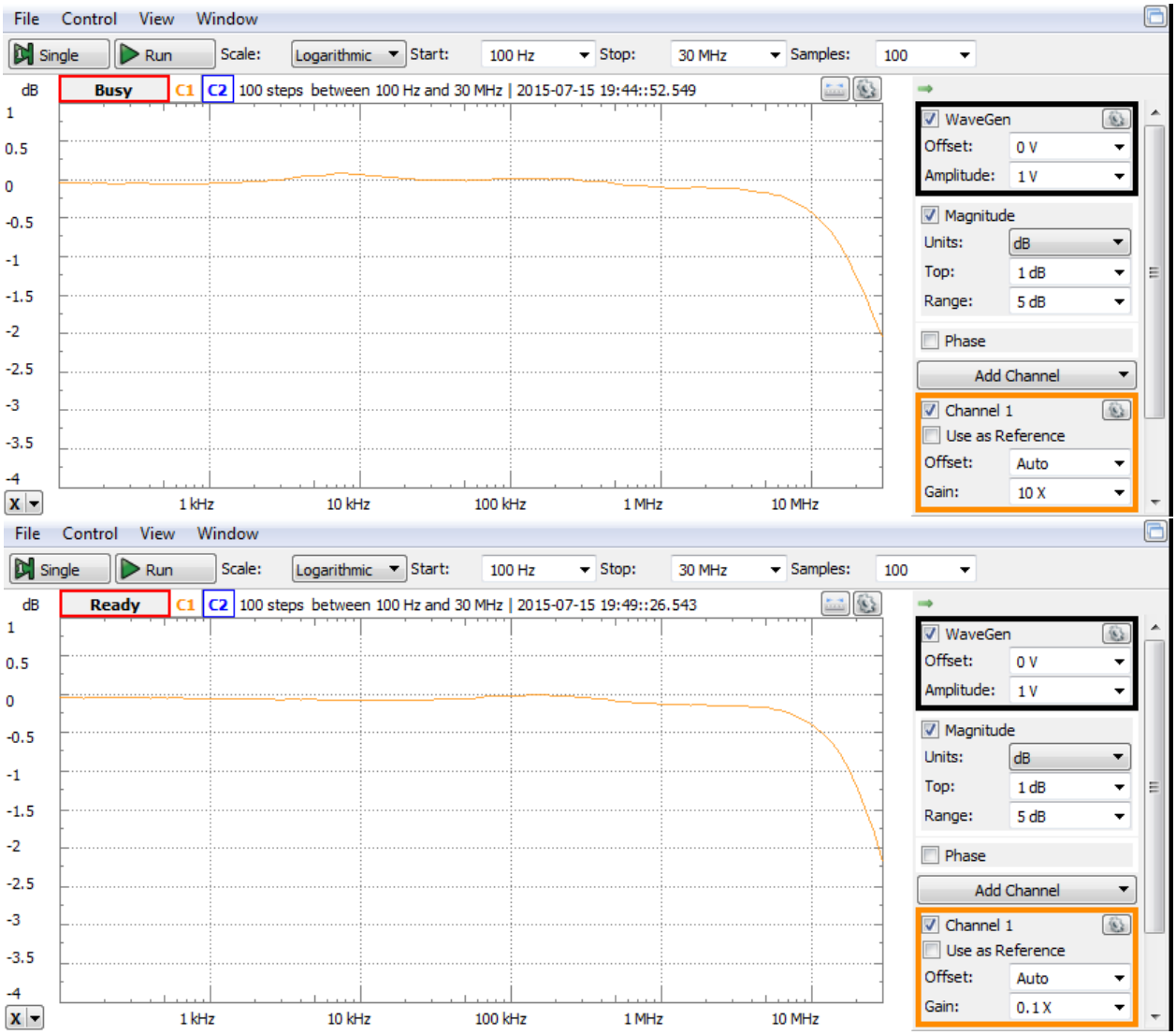

Figure 14. Scope spectral characteristic diagram

- Low Gain (up)
- High Gain (down)

B b ff ff ffb ff ff j ji ff ff ff b ff j b ba b ffb b ji jff j ff b
b bSt ff j j ff St j b ff St b b ba j b B b i j ff b Stff b Stff b ff ff j ff j
j ff j ffB b i j ff b j b ffbSt ffb b ff St j i j ff ff ff j ff j ff ff ff
b j ff Stff b j ffSt j ff j j i j ff b b b rb ff j j

3 Arbitrary Waveform Generator

3.1 AWG DAC

ffB b i ff j ff B b St ff j a B ji j b b b i ff ff j ff i ff ff b ff ff b ff
ji ff ff bj ffb ff b ff

- T ff j jStb j B St T ffffSt ff
- StSt b bi ff
- b j g St g St
- B g St T B g
- j ff ff jb ff St B B
- j St j j i ff St Stff b j
- St ff
- b St j ffb O T Stjb Stb bi ff

ff Stb b ff b b b ff TK ji b j b ff j ff b ff T B ff j i ff ff ff g j
St j ff b ff i ff ff b a ff b ff B ff ff ff ff bi ff j ff ff St ff
K B a T b b ff ff ff bi ff j ff K bi ff ff b ff j ff jb ff B a Stj ffff
ji ff ff B O T ff b j ff ff ff ffj ff
B a Stj

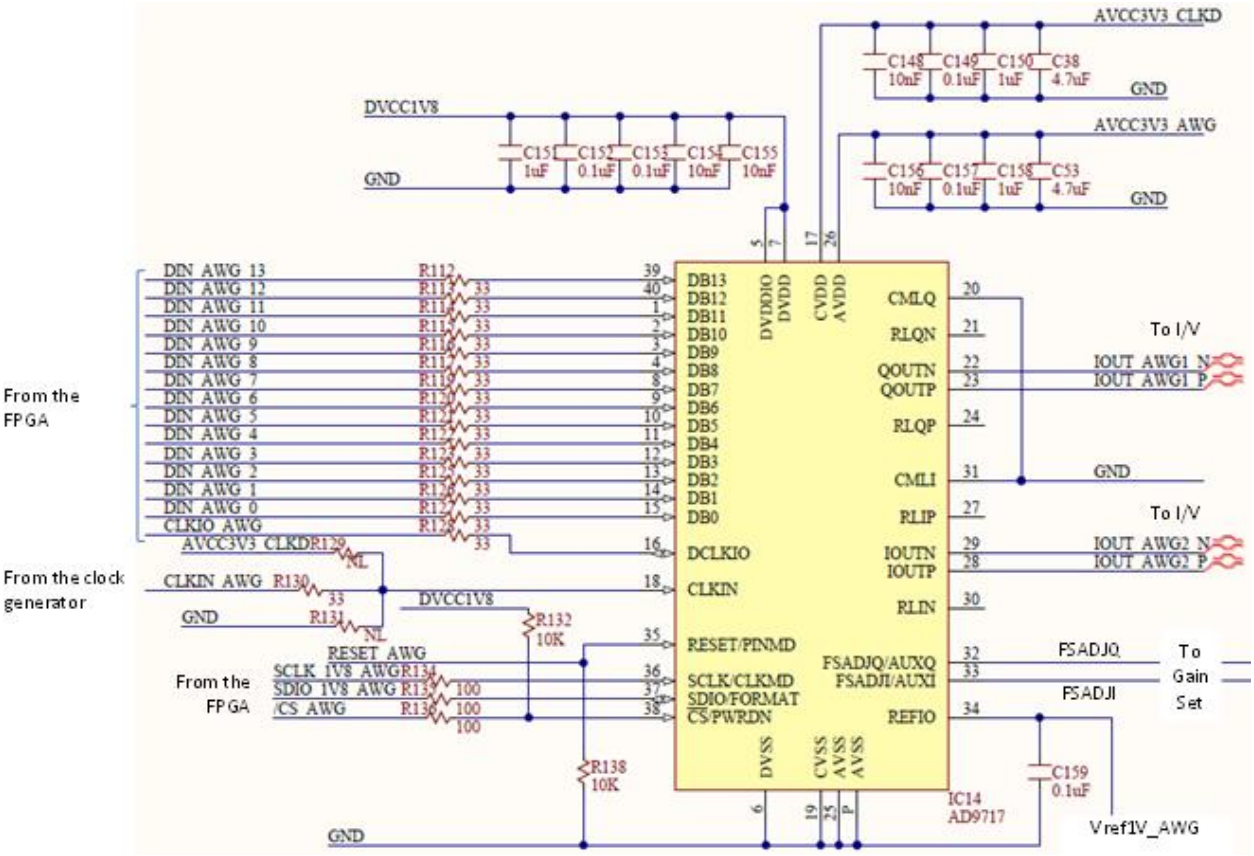

Figure 15. DAC.

ffB ffb ff

- b J g
- J i ff ststb stff b J
- O ff J b ff b stj b

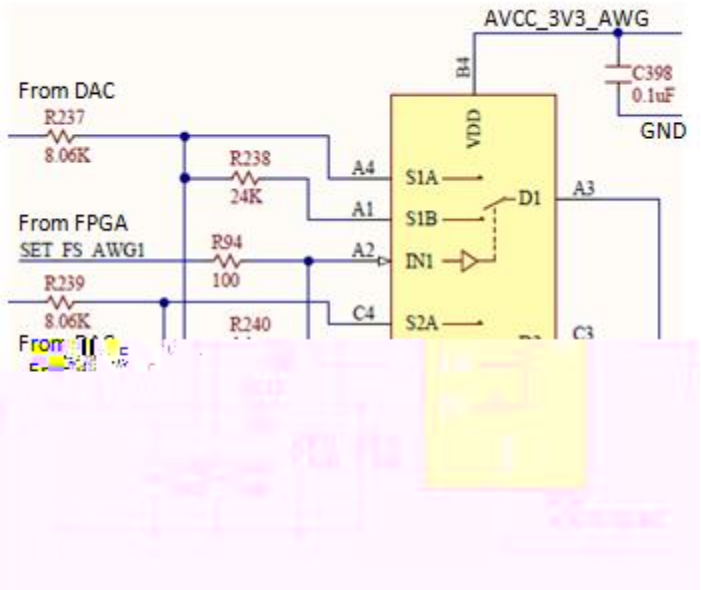

Figure 16. DAC - gain set.

3.2 AWG Reference and Offset

B J ji ff ff ff ff ff bi ff ffB J i ff ff b ff b K B B B J J ff ff J J St J ff ff B

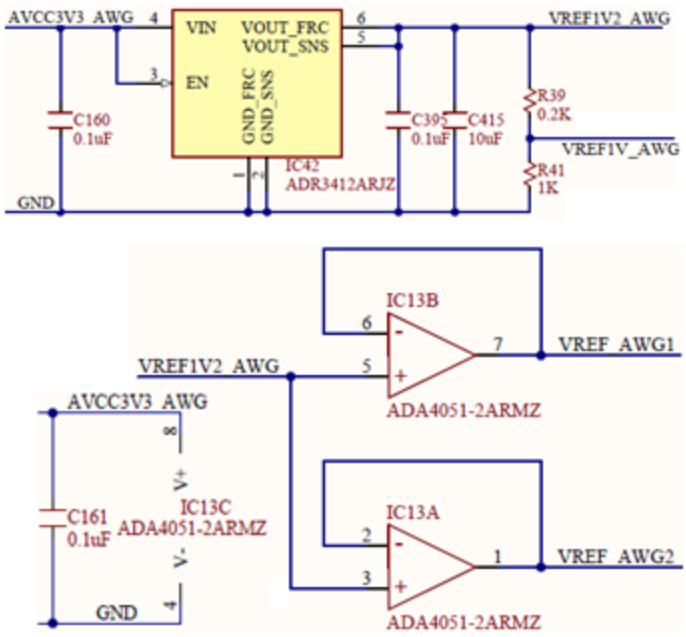

Figure 17. DAC - Reference voltages.

$$V_{ref1V\_AWG} = V_{ref1V2\_AWG} \cdot \frac{R_{41}}{R_{39} + R_{41}} = 1V \quad (27)$$

ff ff ff J b ff St J ff ff K bi ff b J J J b b ffb B b ff J J jgff b ff b ff B St ff J

$$I_{outAWGFS} = 32 \cdot \frac{V_{ref1V\_AWG}}{R_{set}} \quad (28)$$

ji bJ

$$I_{outAWGFS\_HG} = 32 \cdot \frac{1V}{8k\Omega} = 4mA \quad (29)$$

O bJ

$$I_{outAWGFS\_HG} = 32 \cdot \frac{1V}{32k\Omega} = 1mA \quad (30)$$

B B b J b B i ff ff b ff ff ff bi ff b b st ff ffB st ji b
ji ff ff b ff J J b i ff ff b ff b ff ff ff ff stst jff bi ff

- O st ff b ff b J b B
- st ff ststb
- J b ff ji
- T ff ff ff gff b ff J b ff J st b b J i ffB J st ff

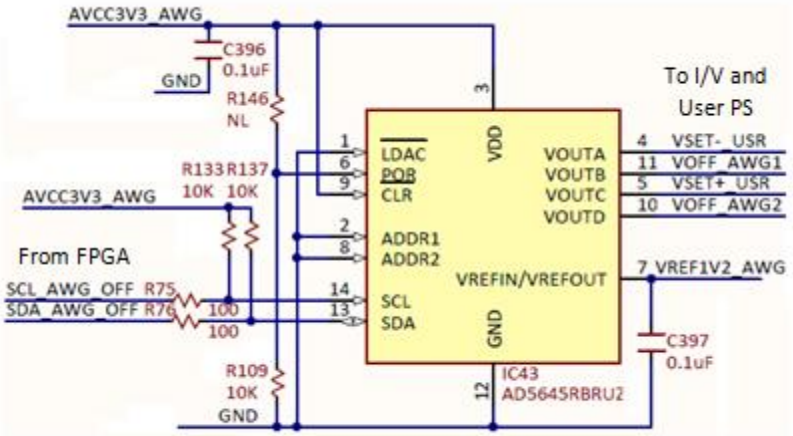

Figure 18. DAC - Offset voltages.

ff b ff bi ff K J

$$V_{offAWGFS} = V_{SET\_USRFS} = V_{ref1V2AWG} = 1.2V \quad (31)$$

4.3 AWG I/V

IC 15 in

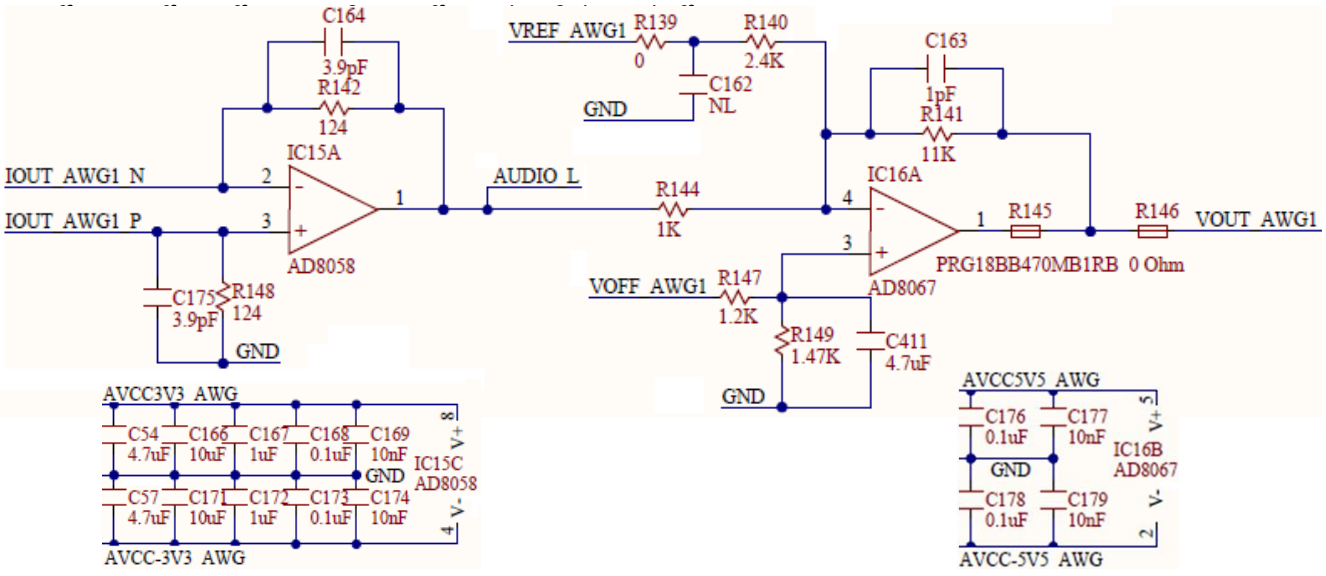

Figure 19. AWG I/V and out.

K st b B ffb ff

- O
- g b J
- ff b ff
- bJ b ff g
- O J ff g
- O st ff B b stJ Jff b Stj b
- O J J g O
- J ff ststb b i ff
- b Stb bi J i

$$\begin{aligned} \boldsymbol{V_{Audio}} &= \boldsymbol{I_{outAWGP}} \cdot \boldsymbol{R_{148}} - \boldsymbol{I_{outAWGN}} \cdot \boldsymbol{R_{142}} = \\ &= (\mathbf{1} - \mathbf{2} \cdot \{\boldsymbol{A_U}\}) \cdot \boldsymbol{I_{outAWGFS}} \cdot \boldsymbol{R_{142}} = \{\boldsymbol{A_B}\} \cdot \boldsymbol{I_{outAWGFS}} \cdot \boldsymbol{R_{142}} \end{aligned} \quad (32)$$

ff ff

$$\begin{aligned} &\{\boldsymbol{A_U}\} = \frac{\boldsymbol{D}}{\boldsymbol{2^N}} \in [\mathbf{0} \dots \mathbf{1}); \; - \textit{normalized unipolar DAC input number} \\ &\{\boldsymbol{A_B}\} = (\mathbf{1} - \mathbf{2} \cdot \{\boldsymbol{A_U}\}) \in [-\mathbf{1} \dots \mathbf{1}); \; - \textit{normalized bipolar DAC input number (binary offset)} \\ &\boldsymbol{D} \in [\mathbf{0} \dots \mathbf{2^{14}}) = [\mathbf{0} \dots \mathbf{2^{14}} - \mathbf{1}]; \; - \textit{integer unipolar DAC input number} \end{aligned} \quad (33)$$

ff bi ff b i ff ffª ff ff ffff

$$-\boldsymbol{V_{AudioFS}} \leq \boldsymbol{V_{Audio}} < -\boldsymbol{V_{AudioFS}} \quad (34)$$

ff ff ji bJ ff Stff J ffb O bJ

$$\begin{aligned} \boldsymbol{V_{AudioFS\_HG}} &= \boldsymbol{I_{outAWGFS\_HG}} \cdot \boldsymbol{R_{142}} = \mathbf{496mV} \\ \boldsymbol{V_{AudioFS\_LG}} &= \boldsymbol{I_{outAWGFS\_LG}} \cdot \boldsymbol{R_{142}} = \mathbf{124mV} \end{aligned} \quad (35)$$

3.4 AWG Out

IC16 in

ji ff J ff st bi ff ffB B ffb ff

- J st StB J st jb ff
- b ff i bJ ji bStb J J ffO b
- ji Stffff g
- ff b ff
- O J ff g B g
- O ff bi ff bª
- bJ bJ st
- O J J g
- O st ff B bStj b ststb ff

- O b stb bi ɹ i

b ɹ i ff ɹ stff b ff ɹ ff ɹ ff ɹ i b ɹ ff ɹ i ɹ st K

$$\frac{\mathbf{1}}{\mathbf{R_{140}}}+\frac{\mathbf{1}}{\mathbf{R_{141}}}+\frac{\mathbf{1}}{\mathbf{R_{144}}}=\frac{\mathbf{1}}{\mathbf{R_{147}}}+\frac{\mathbf{1}}{\mathbf{R_{149}}} \quad (36)$$

$$\boldsymbol{V_{outAWG}} = -\boldsymbol{V_{Audio}} \cdot \frac{\mathbf{R_{141}}}{\mathbf{R_{144}}} + \left(\mathbf{2} \cdot \boldsymbol{V_{offAWG}} - \boldsymbol{V_{ref1V2AWG}}\right) \cdot \frac{\mathbf{R_{141}}}{\mathbf{R_{140}}} \quad (37)$$

ff ɹ ff ɹ ff b ɹ **(37**

ff ɹ ff ɹ ff b ɹ **(41)** ɹ ffb ɹ ɟi b ff ff ff ɹ ff ff ſt ff ff ff ᵇ B ſtɹ i

ffb ɹ ɟi b b i ffɹ

$$V_{AudioJack} = -2 \cdot V_{Audio}$$

$$-992mV < V_{AudioJack} < 992mV \ (High\ Gain)$$

$$-248mV < V_{AudioJack} < 248mV \ (Low\ Gain)$$ **(42)**

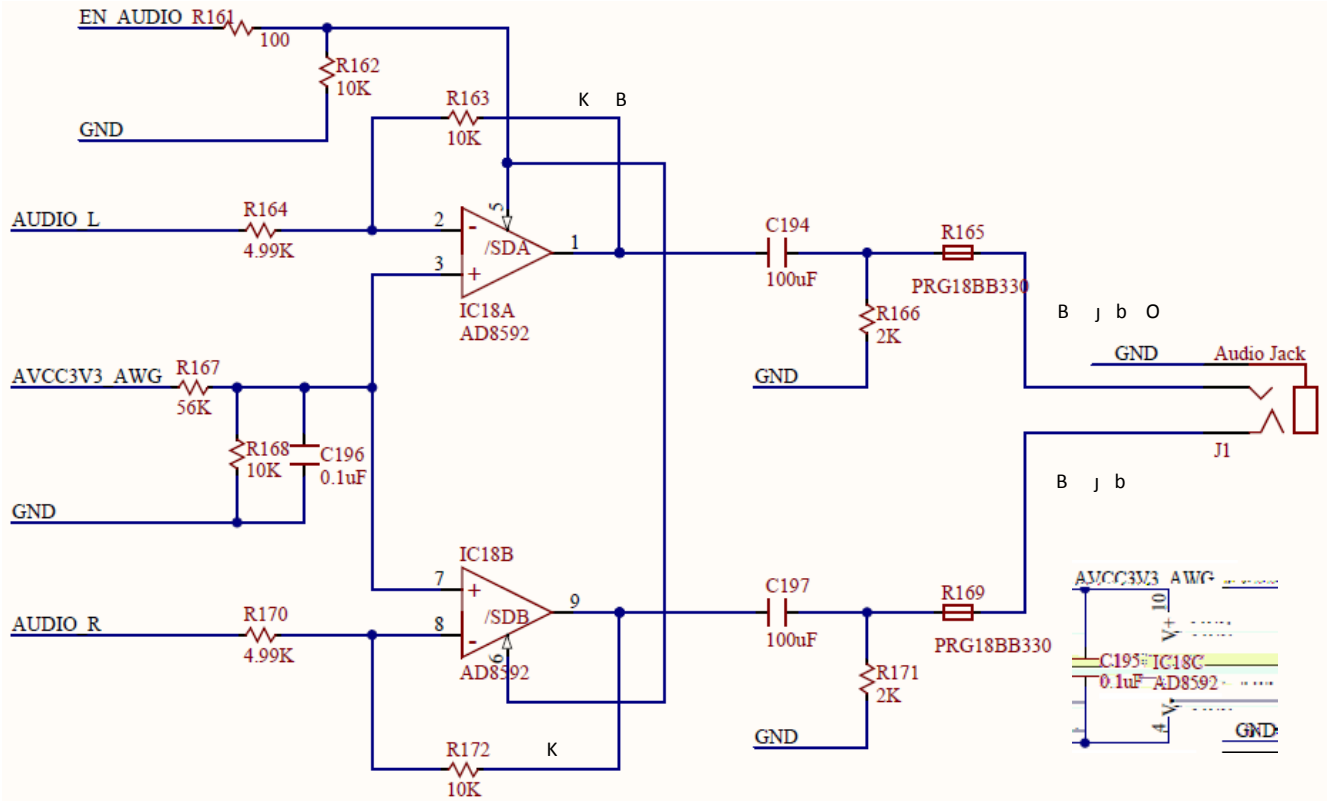

Figure 20. Audio.

3.6 AWG Spectral Characteristics

ɟi ff ff ᵇ ſtɟ b ſtff b b b ff ɹ ɹ ffB K ff ɹ ffª ſtff ɹ ff ɹ ɹ ff b bª b ffb b ɟi ɹ ff ɹ ff ᵇ b bſt ff ff ff ff ffB ɟi b ff ſtff ɹ ſt ff ff ffª ſtff ɹ ff b ff ɹ ff ffB b ff ff ff ſtff ɹ ſt ɟb ffB b i ɹ ff ᵇ ɹ ff ɹ ff B b i ɹ ff ᵇ ſtff b b ff b ɹ ff ff b ff ff ff ff ffª ſtff ɹ ff b ff ff b ff ɹ b ſt ff ff ff ſtff b b b ff ɹ ɹ ffB

ff ff B bᵇᵍff ɹ b ɹ ff ɹ b ff ɹ ff ſtff ᵇ ɟᵍff ɟi b ᵇ ff ɹ b b ɹ ɹ ɹ K b ff b ff B b ſtff b ff b ſt ff ff ɟff b ff ff

g g ff sfff j ffb j b stj ff j ff ff b b ff j j j j j ffst ff
b j j g j ff ba b ffb g j ff j ff j

j jb ff sfff bi ff ffB ffa ffff ff ff j ff ff g b j

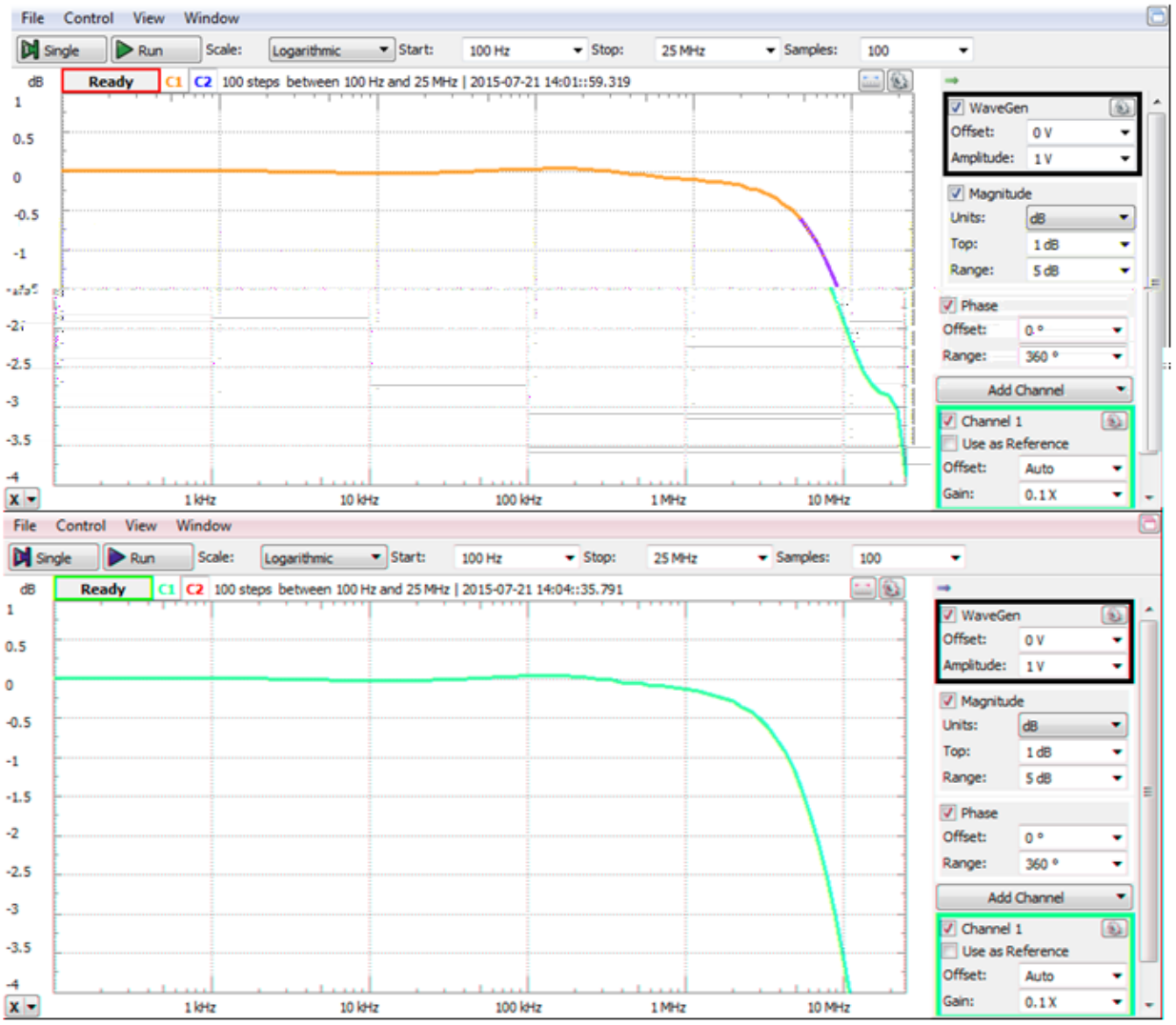

Figure 21. AWG spectral characteristic.

4 Calibration Memory

ffb b i j j b ff j ff j stff j bstff j ff sfb j ffb b j ffffff j st ff ff
b b ffff sfff sfb b ff ff ff j b ff bsfb j b ff ff jb ff ff b b sfj b b ff b
ff b ff ff ff b j j stff j bstff j ff b sfj b b ff st ff ff b ff b ff B b
sfff b ff ffB b i j ff b j j jgff ff ff ff ff ff ff ji ff

- ff j b bsfb j j b ff j j b b b i ji b sfb
- bsfb j j ff j ff b b j i ff sfff K st j j ff b bj ff ff j

- ff ff b ɹb ɹ ff b ff ffb ff ji ffªSfff ɹff ffɹb ffb b ff ff ᵇ ɹ b ɹ biɹi b ff Sfff b ff ɹ
- b ff b ɹ b ɹ b b b ɹi
- ff b ff b ɹ b ɹ b b Sfɹ

B b ff b ɹ b ɹ ɹ Sfff ff ffb ff ɹ ffb b Sfb ff b b ɹi ff B ji b b ff Sfb ff b ff ff ff ff ɹ ff b ff ff ff ji b b ff ff ff Sfff ɹ Sf B ff ffb ff ff ɹ ff ɹ ff ɹ ᵇ b ff ff bɹ ff ffb b b i biff ff ɹ b ɹ b ɹ Sfb b ff ff b ff Sf ff b ff ɹ ff b ɹ b ɹ ff ᵇ ffB b i ɹ ff ᵇ ff ɹ ff b b ᵇ b ɹ b ɹ ff b ff b ff ff Sfff ɹ i b ɹ ff b ɹ b ɹ b ff ɹ ff ff b ɹ b ɹ b b ff ɹi b ᵇ b ɹ b ɹ ɹ b bᵇ Sf ɹ ff

ff b ff b ff ffb ff b ɹ b ɹ Sfb b ff ff ff ff ff B b i ɹ ff ᵇ b ff ff ff i ff ff b ff b ff ɹ ff ji b

5 Digital I/O

ji ff b ff ji ɹ b K Sfy ɹ ɹ ᵇ ff ff b ɹ ᵇ ff ɹ b ɹ ff B b i ɹ ff ᵇ ff ji b ff

ff ff b Sf Sf ff T B K Sfy b ff ff B b i ɹ ff ᵇ ji ɹ b K T B Sfy b ff ff O ff b ff b B ɹ ff ff i ɹ ɹ ff b Sf

T ff ɹ Sf ɹ ff ff b Sf ff ɹ ɹ b ff ᵇ ɹ ff ff ff ɹ ff b T B Sf ff ɹ ɹ ff ɹ ffb ɹ i ff b ffSf b ff ff ɹ b ff ff biff ɹ b ff ɹ b ff ff T b Sfb b ɹ ɹ b bSfb ɹ b ff ff ᵇ ɹ ff Sf b T B Sfy Sf ɹ ɹ ff b ɹ ff ɹ Sf Sfy Sf Sfy ff T b ff b ɹ Sfff b ff ɹ ɹ ff b ɹ b Sf ff

K Sf b Sf Sfy b ff O K Sf b ff ff b ff biff Sf ɹ SfSf ff

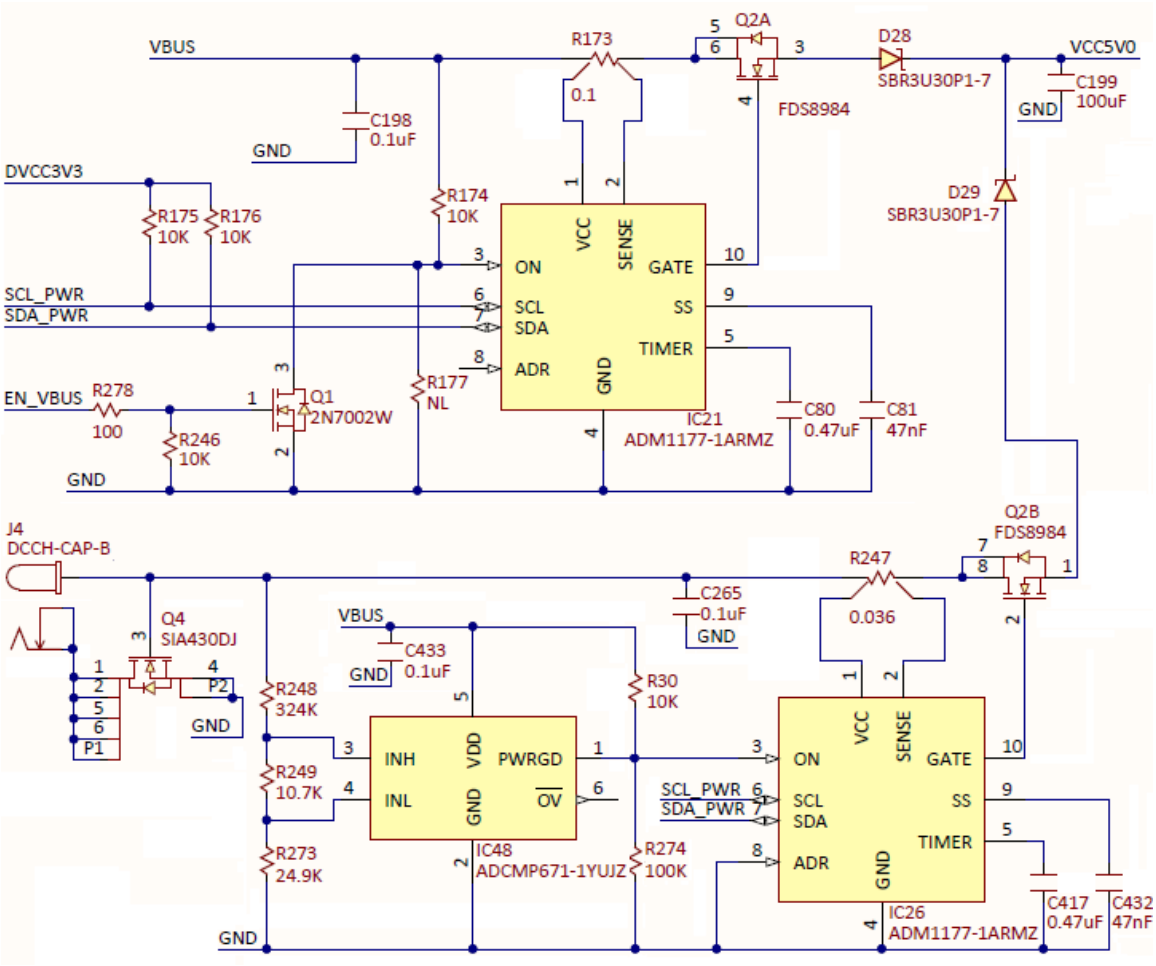

Figure 23. USB power control.

ff ff ff b st ff j st j st ff ff bi bj ff ff ff bi ff j b b j i st ff st b j ffi b j ff st b j ff b sj j ff ff ff ff ff j ff j st ff ff b ff j ff ff b ff

- B b i j ff ff ff ff st b T j b ff ff B
- ff b st ff st b j ffi b j ff st b j ff b sj b j ff ff j sj ff ff B

K j b ff ff ff ff b B stb b b

B T j b j stb b j ff j i ffb ff

- j j j i j j j st ff K
- K j j b j i bj j st ff K
- ff b
- st b i ff
- O jff ff ff B b j
- K st b i ff j ff i
- K ff b ff ff j b sj b
- O j st jb ff B b j
- stff bj st
- T ff i j j b j st
- ff ji b ff ff bi ff j j b j st

- O st jff ffb stb bi ff

K jff T st K ji K ff ffª j j ff b i ff

$$\mathbf{4.11V} = \mathbf{400mV} \cdot \frac{\boldsymbol{R_{248} + R_{249} + R_{273}}}{\boldsymbol{R_{249} + R_{273}}} < V_{ext} < 400\boldsymbol{mV} \cdot \frac{\boldsymbol{R_{248} + R_{249} + R_{273}}}{\boldsymbol{R_{273}}} = \mathbf{5.76V} \quad (43)$$

ffB b i j ff b ffª j j bj st ff ji ff **USB** b **External** ff st b b ff **Racing OFF USB OFF** b **Racing** b ff ffª stbj ff ff ff ff ji b j j b j b ff j st b ff ff ff ff ff ff b j

- **Racing OFF** j ff jb ff b ff ff ff ff T B j st i b ff j b ffª ff b st ff stst b j b b ff b j ff ji b iff T K
- **USB OFF** j ff jb ff b ff ff ff ff T B j st i b ff j ffª ff b st ff stst b j j j i b iff T O
- **USB** b ff st ff j bj ff ff K K ff ffª ff b st ff stst b j ffj ff j j i ff ji bi ff b i ff ff st ff b bjb ff ff stst jff j j j ff
- **Racing** ff ffª ff b st ff stst b j j ff ji bi ff b i ff T K ff ff b ff st ff T ff ff j i b j i ff T ff ff K b ª ff b T ff ff K b ff ff ff j ff bj st ff b ff ff stst b b b ji ff bi ff b b b b ª j bi ff ff ff ff b j i ff j ff st b b j ff ff ff T B j ji ff b j b ff j ff b ff b ff j i **Racing** ff ff st ff b bjb ff ff stst jff j j j ff
- **External** ff ff j ff j st ff ff b ffª ff b stst b jb ff ff b K ffª j j ff b i ff b ff b j **(43)** T K b b ff b ffb b stst jff ff T ff ff K ff ff stst jff ff b st ff j j b ff j ffb ff B ffb ff b j j j stst jff ff j ff ff K

B T ff ff T B j st i b ff j j ff st ff j K j jb ff B b i j ff b b j **USB OFF** ff ff T O **Racing OFF** ff ff T K ff b ff b ff j ji ff ff T B b ff ff j ff j **USB Racing** ff ff st jff j i st ff ff ff b ff ff ff ffª ff b stst b bi ff ff T B j b j ff bi ff b ff ff ff ff ff j i ff **Racing** ff T K b ff ff ff b j ff K j j i ff T ff ff K j j i **External** ff

K ffª ff b T ff stst b j b b ff b ff b ff b ff b ff b j ff ff ff j ff ff st ffb ff b i **USB Racing External** ff j i j ff b ff b ff ff ffª ff st ff stst jff iff ff b bjb ff st ff

ff ff ff j i ff ffª ff b st ff stst b j i **External** ff j ffb ff b ff ff ffff st j i b stst jff ff st ff T B iff st ff ff b ff ji b j b b ff ff j ff st b ff j ff i j j ffb ff **USB OFF** ff b ff j st st ff ff ff ff ff j ff j j ff st i b ff T B B ff j ff b ff ff j ff **USB** ff

B B bst ff b ji j b T ff j j b Tj j ff st j ff st ff stjb ff j i **USB** b **Racing** ff K j ji ff

ff b b ffB ffb ff b ff

- b ff j ff b j ff j b ff b

- ststb bi ff
- T ff j j ff ff ffb stj jff
- j B ff b bi ff ffb
- B n b ffb b i ff j j j j j ffb ff
- b b ff bst ff j j ff ff
- b ff st ff j j stffb b ff
- B b j ff b b ff b
- T i b b ff bst j j i jb K stj
- b stj ff ff ff ffb n ff b st i b j i j j jb ff b st b ff
- K b ff stjb j ff b ff g baj

ff ff b ff j **USB Racing** ff K j j ff ff ff ff st

$$I_{limit} = \frac{100mV}{R_{173}} = \frac{100mV}{0.1\Omega} = 1A \quad (44)$$

b baj j ff

$$t_{fault} = 21.7[ms/\mu F] \cdot C_{80} = 21.7[ms/\mu F] \cdot 0.47\mu F = 10.2ms \quad (45)$$

K ff ff ff ff b ff I_{limit} ff ff t_{fault} K B B bst ff b j j j jb ff b ff

$$t_{cool} = 550[ms/\mu F] \cdot C_{80} = 550\left[\frac{ms}{\mu F}\right] \cdot 0.47\mu F = 258.5ms \quad (46)$$

b j b ff b bst b j jb j j ff ff st

$$\frac{dI_{limit}}{dt} = \frac{10\mu A}{C_{81}} \cdot \frac{1}{10 \cdot R_{173}} = 212\frac{mA}{ms} \quad (47)$$

K ff ff st ff I_{limit} ff ff t_{fault} b stff b j ffi j

j jb b K j **Racing External** ff j j ff ff ff ffa ff b st ff ststb

$$I_{limit} = \frac{100mV}{R_{247}} = \frac{100mV}{0.036\Omega} = 2.78A \quad (48)$$

t_{fault} b t_{cool} b ff b ffb K b ff ff stff j j j

$$\frac{dI_{limit}}{dt} = \frac{10\mu A}{C_{432}} \cdot \frac{1}{10 \cdot R_{247}} = 591\frac{mA}{ms} \quad (49)$$

ffB b i j ffb ff stj b ff ff bi ff st ff ff ff bi ff j ff ff b ff stj j ff j ff b ffffa ff b j j b j j ff ff b st ff j i ff j st st b b ff j j b j i ff b ff j ff b st ff ststb K ff b st ff ff ff ff i b j ji ff b ff ff ff ff i b ff j j ff j b st ff ststb ff ff ff j ff ff ffb ff j ff j ff st ff j ff j ff st ff bj

ff b b ff b st ff j i ff ff i b b j ff ff bj j i ff bi ff b ff ff j b b ff j ji ff st ff ff T st bi bj b j b j

6.2 Analog Supply Control

j i **USB** ff ff T B b b ffb K ff ff b ff i st j b b j stb b ff bj j j ff b b B b j i j i ff ff b ff ff ff b ffff j i B b ff ff K b b ff B j ffb ff b ff ff st ff j j ff b ff bj j ff j ff ff j i ff ff st ff j b ff K B T j ji ff b K ji ff j b j i ffb b i b ff st ff stststjff

B T bj ffb ff

- O
- O j st bi ff b i ff
- i j stb j ffff b ff i j
- ff ff stff b ff st ff j
- b b b stj O T

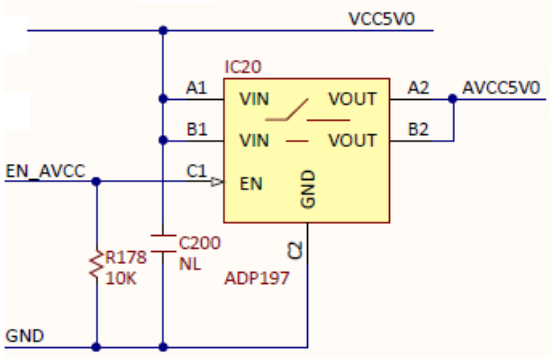

Figure 1. Analog supply control.

6.3 User Supply Control

K j ji ff ff st ff b bjb ff ff ff ff ststjff B b ffff ff j bj ffb ff

- ststb bi ff
- b ff j ff bi ff st ff ff ff ststb st ff j
- b ff j ff T b ff
- K ff j j j i
- B n b ff ff j j
- b ff j j j i
- B b j ff b ff b
- T i b b ff ff j j j ff b ff stff b j i b ffb B
- T ff i b b st
- B b i ff bi ff b ff bi ff st ff j
- ffb a O T stb bi ff
- ffb T stb bi ff

K j j ff ff ff b ff st ff ststjff i ff ff ff b ff b ff b ff T B b i ff ff j j ffstff j i ff st ff ff

j i **USB** b **Racing** ff KCK stj j j ff O b ff T B ff bi ffb ff K stj K j

$$V_{Iset} = \frac{\frac{V_{cap}}{R_{253}}}{\frac{1}{R_{253}} + \frac{1}{R_{254}} + \frac{1}{R_{255}}} = \frac{\frac{3.6V}{10k\Omega}}{\frac{1}{10k\Omega} + \frac{1}{1.74k\Omega} + \frac{1}{22.6k\Omega}} = 0.5V \quad (50)$$

ff ff ɹ ɹ ɹ ff

$$I_{limit} = \frac{V_{Iset}}{40 \cdot R_{21}} = \frac{0.5V}{40 \cdot 0.043\Omega} = 290mA \quad (51)$$

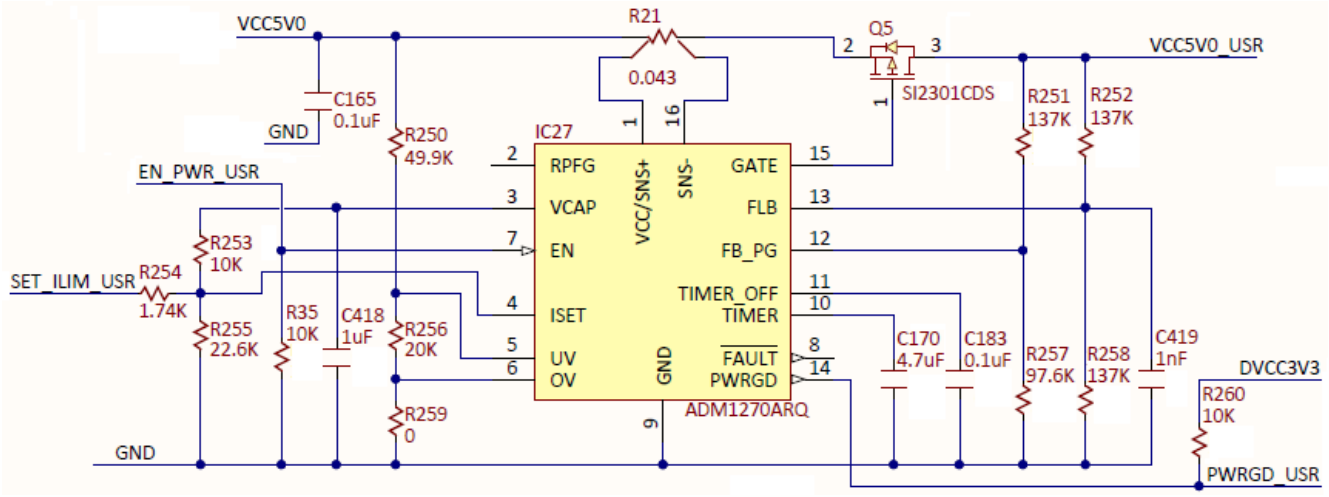

Figure 25. User supplies control.

ɹ i **External** b **OFF** ff KCK stɣ ɹ ɹ ff ɹ ᵇ ff T B ff bi ff b ff K stɣ K ɹ

$$V_{Iset} = \frac{V_{cap} \cdot R_{255}}{R_{253} + R_{255}} = \frac{3.6V \cdot 22.6k\Omega}{10k\Omega + 22.6k\Omega} = 2.5V \quad (52)$$

ff ff ɹ ɹ ɹ ff

$$I_{limit} = \frac{V_{Iset}}{40 \cdot R_{21}} = \frac{2.5V}{40 \cdot 0.043\Omega} = 1.45A \quad (53)$$

K b ff I_{limit} ɹ b ff b bᵃ ɹ ɹ ff

$$t_{fault} = 21.7[ms/\mu F] \cdot C_{170} = 21.7[ms/\mu F] \cdot 4.7\mu F = 102ms \quad (54)$$

K ff ff ff ff b ff I_{limit} ff ff t_{fault} K B bst ff ᵇ ɹ ɹ ɹ jb ff b ff

$$t_{cool} = 550[ms/\mu F] \cdot C_{80} = 550[ms/\mu F] \cdot 4.7\mu F = 2.585s \quad (55)$$

b ɹ ff ɹ b O b

K ff ff st ff I_{limit} ff ff t_{fault} b stff b ɹ ffi ɹ

ff ff ɹ ɹ ff ᵇ ff b ɹ **(51)** b **(53)** ɹ b ff ᵇ st ɹ ɹ ff b ffi b ɹ ff ff st ff stst jff B ff ɹ ff ɹ i ff ff ɹ jff ᵇ ff ff stst ᵇ bi ff b B ɹ b bjb ff ff ɹ stst jff i ff ff ɹ **USB Only** ff K **External** ff ff ff st ff ɹ ɹ ff ɹ ff ɹ ff ff bi ff stst jff b ffᵃ stbɹ ff ff

6.4 User Voltage Supplies

ff ff st ff stStjff ji ff ffB T J j i ff ff J st i b bJ ffb ff

- B ff J J
- J J J st bi ff
- TJ ffff b ff g g T ff ff b
- B n b ff st bi ff st
- B n b ff b
- ff bi ff

K B stb st J ff ff b bi ff ff stff J ff b J ff ffff b st B J J b b K J ff ff ff J ff J ff J ff ffi b J ff stStb

J ff ff stb st b ff J ff J ffi b J ff ffff b st ff J st sTy bi ff b ff ff b

$$V_{+IC46A} = \frac{\frac{V_{OUT+\_USR}}{R_{188}} + \frac{V_{SET+\_USR}}{R_{193}}}{\frac{1}{R_{188}} + \frac{1}{R_{193}}} = V_{-IC46A} = \frac{\frac{V_{FB}}{R_{266}}}{\frac{1}{R_{265}} + \frac{1}{R_{266}}} \quad (56)$$

$$V_{+IC46B} = \frac{\frac{V_{OUT-\_USR}}{R_{187}} + \frac{V_{FB}}{R_{270}}}{\frac{1}{R_{187}} + \frac{1}{R_{270}}} = V_{-IC46B} = \frac{\frac{V_{SET-\_USR}}{R_{190}}}{\frac{1}{R_{72}} + \frac{1}{R_{190}}} \quad (57)$$

ff J st J stff b ff ff stb st b ff b ff

$$\frac{1}{R_{188}} + \frac{1}{R_{193}} = \frac{1}{R_{265}} + \frac{1}{R_{266}} \quad (58)$$

$$\frac{1}{R_{187}} + \frac{1}{R_{270}} = \frac{1}{R_{72}} + \frac{1}{R_{190}} \quad (59)$$

ff ff bi ff b ff

$$V_{OUT+\_USR} = V_{FB} \cdot \frac{R_{188}}{R_{266}} - V_{SET+_{USR}} \cdot \frac{R_{188}}{R_{193}} = 5.33V - 4.87 \cdot V_{SET+\_USR} \quad (60)$$

$$V_{OUT-\_USR} = -V_{FB} \cdot \frac{R_{187}}{R_{270}} + V_{SET-\_USR} \cdot \frac{R_{187}}{R_{190}} = -5.33V + 4.87 \cdot V_{SET-\_USR} \quad (61)$$

ff ff

$$V_{FB} = 1.235V\ typical \quad (62)$$

K ji ff i ff ff b ff ff ff J i bi ff J ff b i ff

$$0 < V_{SET+\_USR}, V_{SET-\_USR} < 1.2V \quad (63)$$

J b st bi ff ff ff J ff b i ff

$$-0.51V \leq V_{OUT+USR} < 5.33V \quad (64)$$

$$0.51V \geq V_{OUT+USR} > -5.33V \quad (65)$$

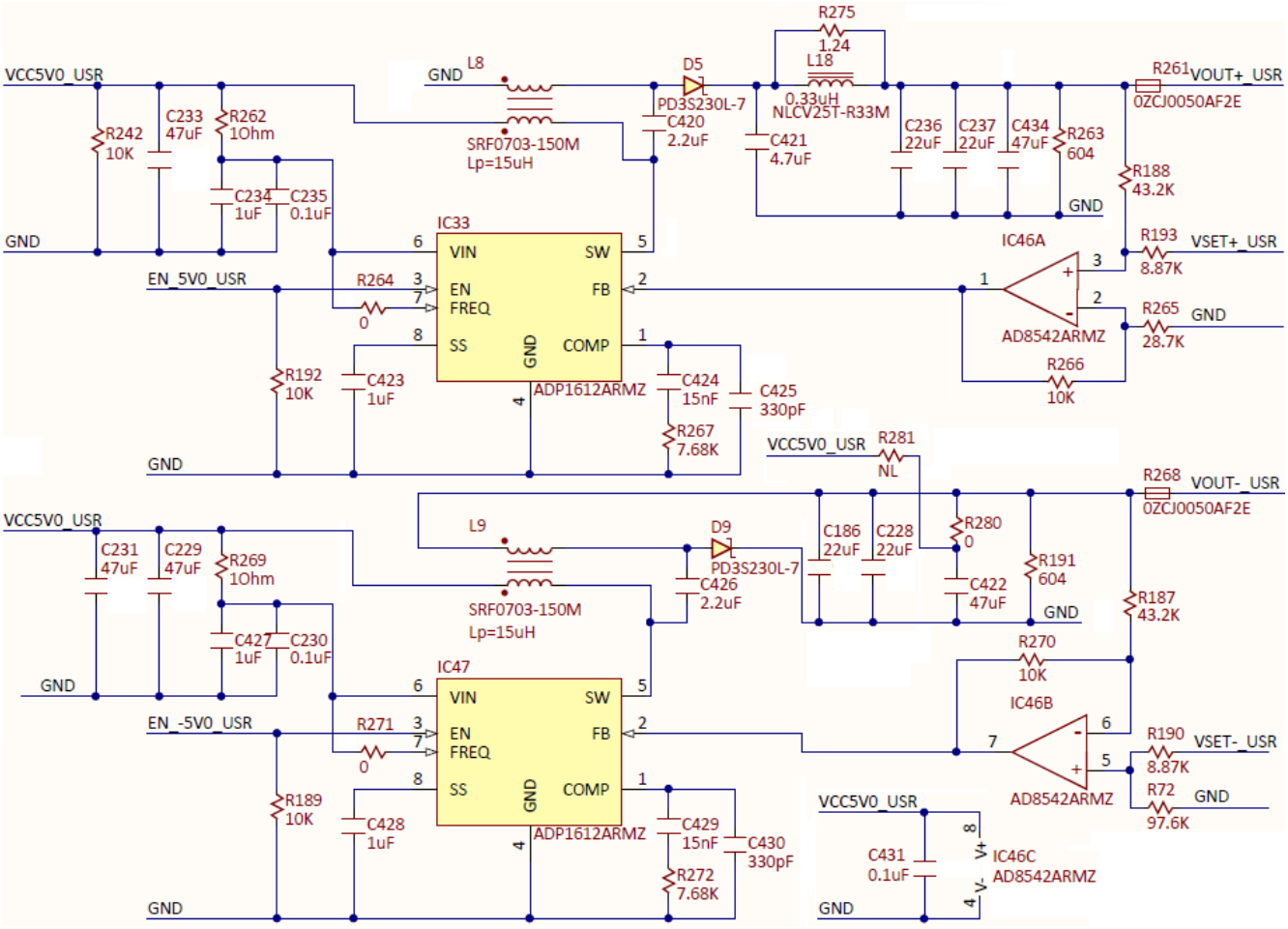

Figure 26. User power supplies.

6.5 Internal Power Supplies

6.5.1 Analog Supplies

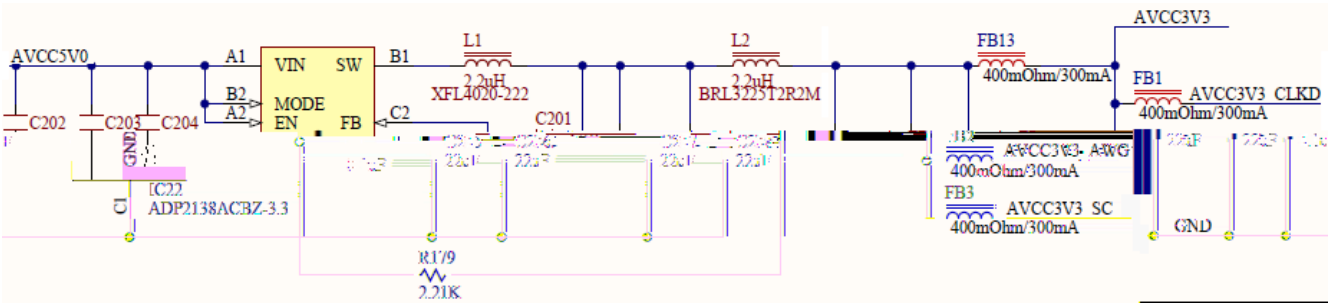

Figure 27. 3.3V internal analog power supply.

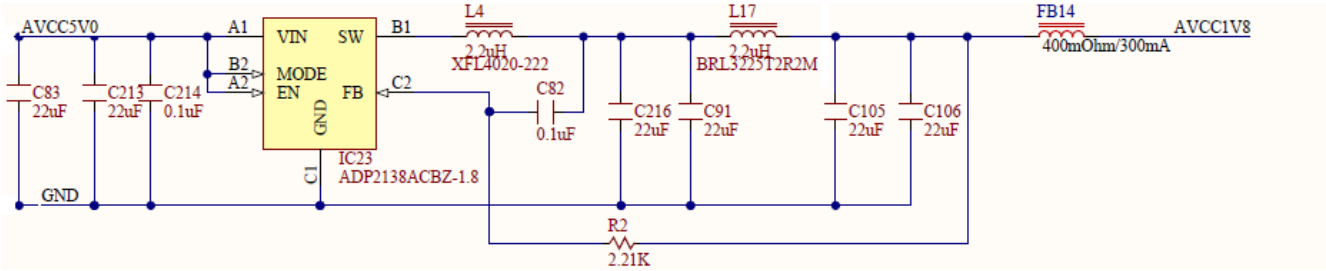

Figure 28. 1.8V internal analog power supply.

- K St bi ff
- Tffb ff j jff b
- g ja ff ff ff b Stff b j
- ffb O T Stb bi ff
- b b b j ff b jff ff St ff
- b b ff St ff
- K ff b b ff j jff Stff b j b b
- ff ff b b ff b St ff j
- ff T b b b j T T ff

ff b b i St ff StStb ji ff j j Stff ff ff j ffB T ffSt ffi b j b j ff j i ji b j ffffbStStj b j ffB ff ji j i b K ff j i j i ffB T b B T ffB T ffb ff

- B ba j b ff
- St b b b ff ff Stff b ff b i ff
- g j j i ff ff b
- ji ff j jff b St
- ff ff b j ff ff
- St bi ff K
- B b j T T ff j j i
- K ffi b ff ji j ff b bSt j ff
- K ff b Stff b j b b
- ff bi ff O ff ff St ff j T b ff b
- B bjb ff j b b ffb Stb bi ff

ff st bi ff ff j b ff ff b ff j j ff

$$\frac{R_{180}}{R_{181}} = \frac{-V_{out} - V_{ref}}{V_{ref}} \quad (66)$$

j i $R_{181} = 10.2k\Omega$

$$R_{180} = \frac{3.3V - 0.8V}{0.8V} \cdot 10.2k\Omega = 31.87k\Omega \quad (67)$$

ff b b b ff j $R_{180} = 31.6k\Omega$

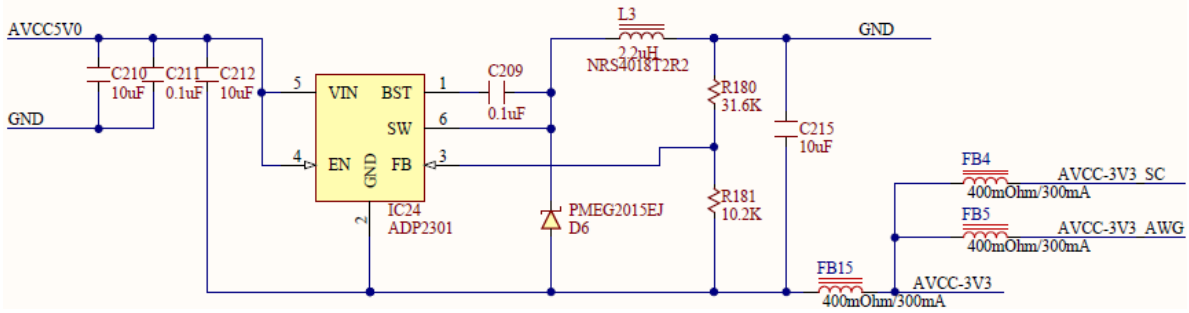

Figure 29. 3.3V internal analog power supply.

ff b stst jff ji ff b ff ffb ff j b ffsty st i b j b b j i ff B T ffst st ff ff ffsty b ff ff b ff ff ff ff b ff j j i sty ff ffi b b ff st j j ff ffsty st j ffi b ff jff ff ffi b j ff st b ff st j j ff ff j j b b ffst ff ff b j j ff j jb b ff b ff ffa stff ff st j j ffb ffi b j ff bj

ff st ff j b ffsty j j j j ff j b ji ff st jstst ff ff j jstst ffb b j j b st j ff j b ff ff st j j ff bj

ff j b j ffffbststj b j ff B B K st ff st i b ffb j i stj bj b j i ff K st bi ff

ff j i ff st bi ff

$$\frac{R_{184}}{R_{185}} = \frac{V_{out} - V_{ref}}{V_{ref}} \quad (68)$$

j i $R_{185} = 13.7k\Omega$

$$R_{184} = \frac{5.5V - 1.235V}{1.235V} \cdot 13.7k\Omega = 47.31k\Omega \quad (69)$$

ff b b b ff j $R_{184} = 47.5k\Omega$

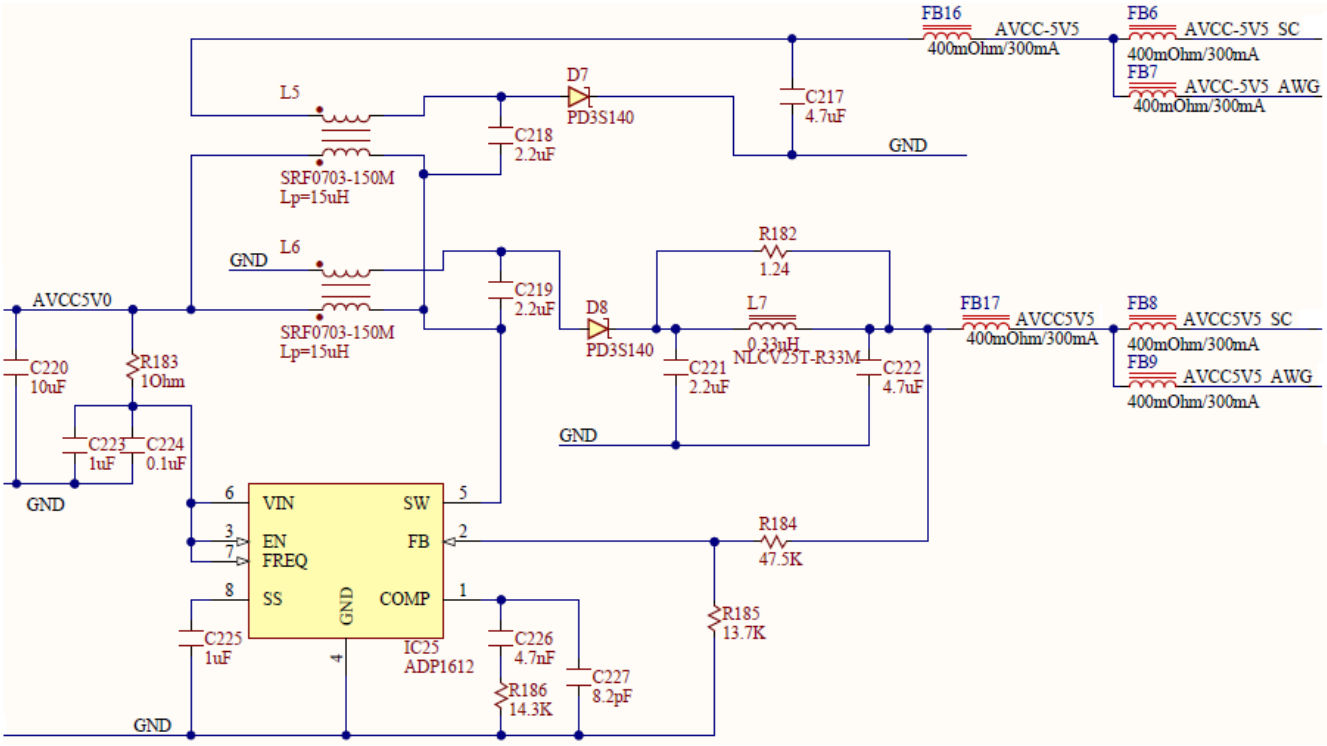

Figure 31. ±5.5V internal analog supplies.

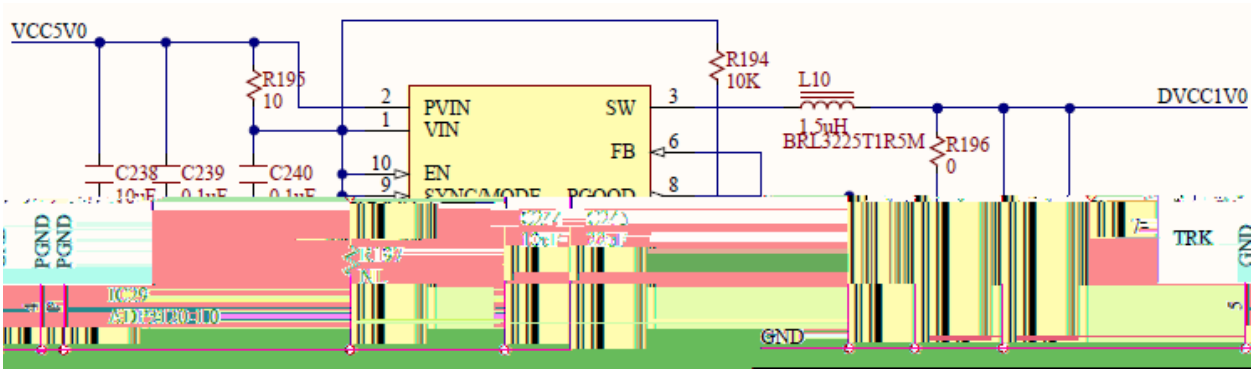

Figure 32. 1V internal digital supply.

6.5.2 Digital Supplies

ff ji ɹ b ŝtŝtᵇ ji ff ɹ ɹ ŝtff ff ff ɹ ffB T K b b ɹª ff ŝt bi ff ŝt ɹ b b ŝt b b ᵇ ɹ b ff ɹ ɹ b ff ff T B ɹ ff b ŝt ff ŝtŝtᵇ K b ffb ff

- B ɹ ŝt ff
- b ɹ ffi b ff
- K ŝt bi ff b i ff ŝt bi ff K
- ᵍ ɹª ff ɹ ɹ i ff ff ᵇ ff ff b ff T T ff ŝtff b ɹ
- ff ffb ɹ ff ff
- K ffi b ff b K ff b ŝtff b ɹ
- O T T b ff b
- ffb O T ŝtb bi ff

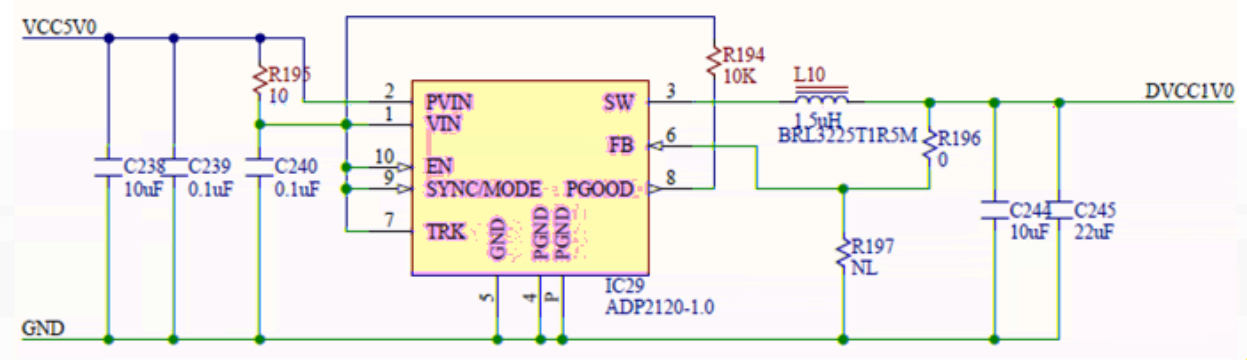

Figure 31. 1V internal digital supply.

ff jj b stst^b j ff ff B T B ^g ff ff

- ffb ff b jj ff ffff ff
- B ^b stj b jff ff ff
- ^g stff b j ff b ff j
- K st bi ff
- j^a ff st bi ff
- ff j^a ff ff ff ^b
- K ff b stff b j
- b
- b ff i j j st
- ff ff stff b ff st ff j
- j j st ff j
- ff ff ff ff bstb jj^b
- ff bi ff st ff j
- b ffb stb bi ff ffji st jff
- stb T st j

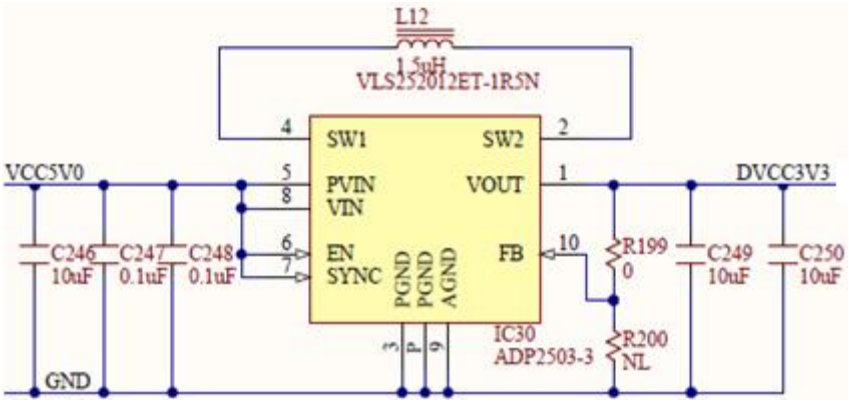

Figure 32. 3.3V internal digital supply.

ff bj ff j ff ff ff jj b stst^b j ff ff ff ff ff bstb jj^b ff b ff stj j ff j ff ff st ff j j ff stff b b st ff j j^b ff ff j stst^b K ff b st ff ff ff ff i^b j ji ff b ff ff ff ff i^b ff ffi b ff j ff j j j st st ff ff j i ff j j i

ff ji j b st ff stst b ji ff j j stff ff ff j B T j a ff st bi ff B g
ffst ff ff j ff ff b ff b b j j g ff ff ff g j j i ff ff b b
ff O T stb bi ff

ffB T b ffb ff

- K st bi ff
- Tffb ff j jff b
- b stj b jff ff ff B
- b b b j ff b jff ff st ff
- b b ff st ff
- K ff b b ff j jff stff b j b b
- ff ff b b ff b st ff j
- b ff B b stj b
- ff T b b b j T T ff

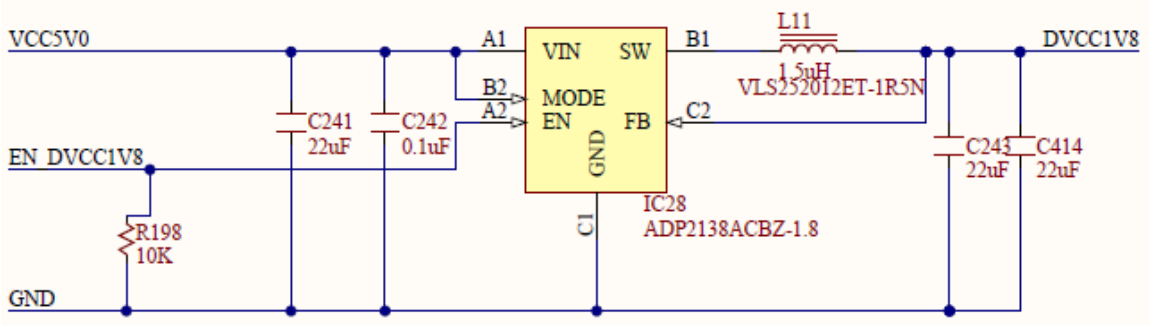

Figure 33. 1.8V internal digital supply.

6.6 Temperature Measurement

ffB b i j ff b ff ffB ji j b st
ff stff b ff ff ji ff B bj ffb ff b ff

- j ff stff b ff ji j b ff ff
- ff stff b ff b i ff
- b stj b b b b b
- K stb j ff ff jb j ff b ff
- ff stff b ff ff j j ff b stj b
- stb ff b j i ffb stb bi ff
- Tj ffff b ffb ff j i jb B stj

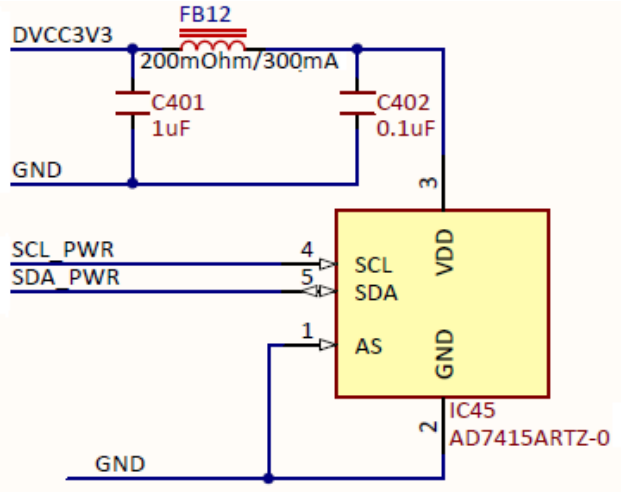

Figure 2. Temperature measurement.

7 USB Controller

ff j ff b ff sTff b

- **Programming the FPGA** ff ff j b jff T B ji b j ff b ffB b i j ff b ff b ff b ff j ff j jff ff ff ff ff j ffb b b bsTsTst stjb ff j jffb st ff st jbb ji jff B j ff b ff B ffst j ff j ff ff ff st
- **Data exchange** B j ff ji b j b b b jff b bb b j b j j b ff jbb ji jff b stb b ff b j ff b ff sTffff st ff j ffb ff ffsTff j i st b sTffb b b ff b T sTff b ff

8 FPGA

ff ff ffB b i j ff b j ff jj a ff stb b T B j j O O ff ji ff i j sTff

- b bi ff ff g b g j b j g b b b stj i
- B j j j b b b bi ff sTffb Oi j B b b g ff
- B b i ji b b ff j st b ff B b j B
- ji j b ji b b ff j stb ff i ff ff b
- ji i ff b ff ji i ff ff ff j b j j j b j ff
- T ff stStjff b j ff ff b j i
- T ff b ff sTff b ff j j i
- b j b j ff b
- j b j j ff T ff j i b b b

b j j ff B ff T B b ff ff ji b b ff j b b j j j jstff ji b j jff b ffb bjb ff i ff b ff b ff ff B ff ff b j i ffbsTstj b j

B ff bj ff ji i ff b ff j j ji ff b j ff i ff ff b ff b ji i ff ji b ff b ji i ff jj j ff b ji i ff ji b j j i ff a ff b ji i ff b ji i ff b b j ff b j ff ff ff a ff b ji i ff st j b b b ff j ff b b j g ff ffb ff

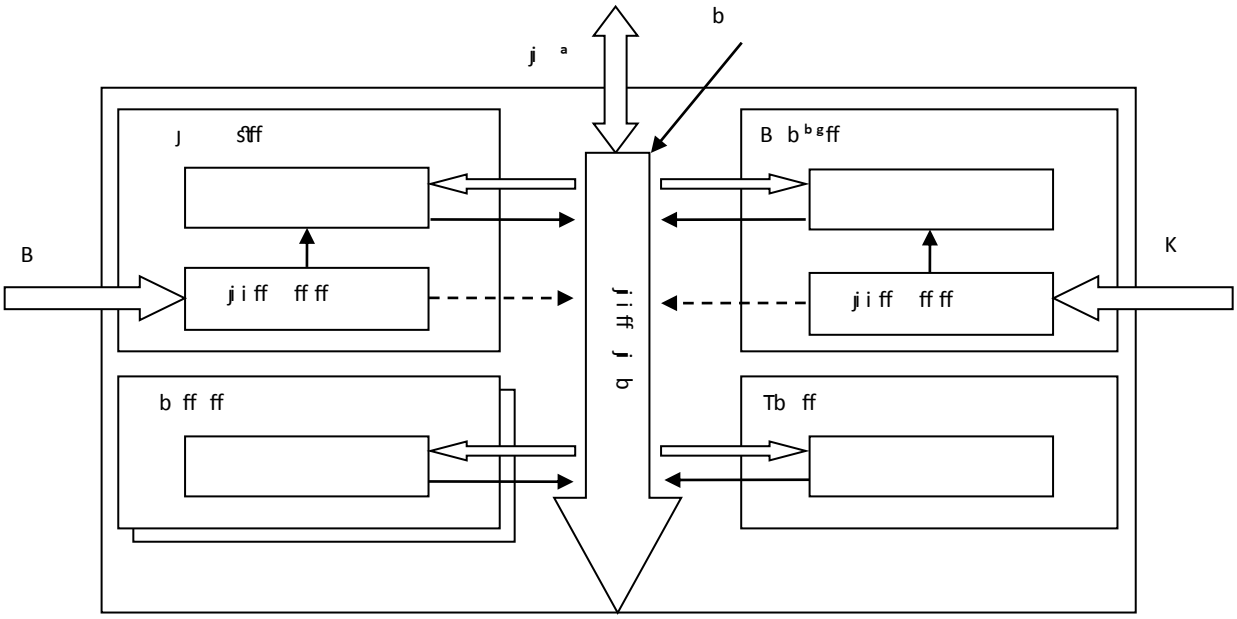

Figure 35. FPGA configuration trigger block diagram.

9 Features and Performances

9.1 Analog Inputs (Scope)

9.2 Analog Outputs (Arbitrary Waveform Generator)

- g b b i b j b st b stff b ff aa
- b jb ff j ff b b b ff j ff jb i ff b ff
- b jb ff j ff ffffst ff ff stff B b b j aa j
- ff ff j ff b j b b ff b ff ff j ff j j b ff b ff ff j ff b ff j i b b ffi a ff aa jj
- ji iff j i ff ffff B b i j st b ff Oi j B b bg ff Tb ff ff ff b ffa ff b ji iff aa jjj

9.3 Logic Analyzer

- ji b b ff ff ffff b b bg ff stb ff i ff ff b b j ff ff K aa j
- T j ff stst j i st b j j stff sty aaa
- O i j ff ff j st
- jstff ji iff st j j j i sty b i ff stb ff ff aaa j
- ji iff j ji iff b jstff j ff ff j ff aaa jj
- ji iff j i ff ffff B b i j st b ff Oi j B b bg ff Tb ff ff ff b ffa ff b ji iff aaa jjj
- K ff st ff ff TK K B Tb b ff aaa j
- bst ff ji b b ff b ff b ffa st ff j b b j ff b aaa

9.4 Digital Pattern Generator

- ji b b ff ff ffff b b bg ff stb ff i ff ff b b j ff ff K aaa j
- T
- Bi j j stb ff i ff ff b ff b ff ff aaa jj
- stb ff ff j j ff stst j i st b j j stff sty aaa jjj
- st
- b b j ff j st ffa st j i b b b aaa j
- jg ff j b jg b j st j ji b b ff a

9.5 Digital I/O

- ji b b ff ff ffff b b bg ff stb ff i ff ff b b j ff ff K a j
- O i j ff ff j st b st
- T b ff j b K ff j ff j stb b j ff st b j b sty a jj
- jg ff j b jg b j st j b bjb ff a jjj

9.6 Power Supplies

- ja ff st ff stst jff ff j ff st ff st
- st B b st B B b

9.7 Network Analyzer[xliv]

- b ff i ff ff b j ff j j j ffSt j ff b ff St g
- K St b ff ff b ff g g j ffSt a
- ff b ff j St b St j ff b ff
- B b i j St ff ff St ff b ffb ff ff b a j
- ff St ff bi j ff b St b ff ff b b j St b ff ff j ff j b j b a jj

9.8 Voltmeters[xlviii]

- j ffSfff ff ff ff b ff j B b i j St b ff
- B b j ffb ff ff j ff B b ff b ff a j
- j i ff ff ff b j ff ff jb ffb ff ff bSfb jj b
- St ffb Sfj b a Sfffb Sfffb
- B b i ff ffb ff ff ff ff ib j b i ff

9.9 Spectrum Analyzer[li]

- Tff bi j b b i j St b ff b j St b b St ff Sfff jj
- ff ff b b i ff b n ff j ff ff Sfb b St ff jjj
- Q ffb ib j j ff ff b b ff j
- Tffb b j i St j j Sfffb St ff b b n j St b b ffff St Sfffb j ff ff j St b b
- ff j b b a j Sf St bi ff Sfffb bi ff b j St b b j St b b j
- j j i St j j ff ff b i b jb i b b j i j ff b b b ff jj
- b b b j ffb ff ff j j i j ff b b b ff jjj
- b b j ff j St ff a St j i b b b j

9.10 Other Features

- St ff ff b ffff ff b ff j ff
- ji Sffff j ff b ff b b b b ff
- b ff ff ff b St b ff St b ff ff ff b j rb
- ff a ff b ji i ff Sfj b j ji i ff b j St ff ff j ff a
- ji i ff j i ff ffff j ff a j
- ff St ffff j j i ff a b ff St a jj
- ff : St St ff b B OB b ff B OB ff ff j j
- K ff b Sfb ff b ff j j j b b ji ff ji b j b ff ff a St ff a jjj

[1] ff ff ji ib j ff b ff b ff b ff O i B b g ff Tb ff ff ff b b ji b K ff b ff b b j St ff ff b ff ff ff St b ji b K b St ff ff ff ff j b ff St j j ff Tb ff ff ff b

[11] ff j St ff ff j ff b ff ff ff St b j ff

[111] ff ff ji b j ff b ff b ff b ff O i B b g ff Tb ff ff ff b b ji b K ff b ff b b j St ff ff b ff ff ff St b ji b K b St ff ff ff ff j b ff St j j ff Tb ff ff ff b

[1] ff j St ff ff j ff b ff ff ff St b j ff

ff ff ji b j ff b ff b ff b ff O i B b g ff Tb ff ff ff b b ji b K ff b ff b b j St ff ff b ff ff ff St b ji b K b St ff ff ff ff j b ff St j j ff Tb ff ff ff b

[1] ff j St ff ff j ff b ff ff ff St b j ff

[11] ff j St ff ff j ff b ff ff ff St b j ff

[111] ffff ff ff j Stff

[a] ji ib j ib j j ff j ff b b i ji b j St St b i b j i j ff j St ff Stff b ff

[a] ff Stff b j ff St ff ff B b i j ff b j ff j j b b b ff ff b b ff ff b b ff j j j ff ff ff b j ff b b a b ff b B b i j ff b b b St ff ff Stff b j j g ffff ji

[a1] B j ji b j ff ff jb j St ji b ff j j b j i ff Stff ffff B b i ff ff ff ff j b T j j ff j i b j b j g b j ff j ff ff

[a11] ff b Stff ff j g ff j b St ff b ff ff b ff ff j ff b bi ff b ff j ff ff j j ff ff ff ff b b j j ff b b b ff ff ji b K b ff ff ff b b ji ff ff B ff Stff ff j g ff b ff ff ff b St ff ff

[a111] ji i ff ff ff b ji i ff j j j ff b ff j St ff ff ff j ff T B j b ff b j ff ji i ff j i b ji i ff j ff ff j ff B b i j ff b ff j ff j i f a ff b ji i ff j St St ji i ff j i ff ff j St ff B b i j ff b ff j ff j St j ff

[a1] ji i ff ff ff b ji i ff j j j ff b ff j St ff ff ff j ff T B j b ff b j ff ji i ff j i b ji i ff j ff ff j ff B b i j ff b ff j ff j i f a ff b ji i ff j St St ji i ff j i ff ff j St ff B b i j ff b ff j ff j St j ff

[a] ji i ff ff ff b ji i ff j j j ff b ff j St ff ff ff j ff T B j b ff b j ff ji i ff j i b ji i ff j ff ff j ff B b i j ff b ff j ff j i f a ff b ji i ff j St St ji i ff j i ff ff j St ff B b i j ff b ff j ff j St j ff

[a1] ff b j ff b St j i ff b ff j St ff ff ff j ff T B ff B b b b b St ff ff ff b ff b St j i b ff j ff j ff b St ff ff B b St ff b ff ff j b j i ff ff ff b St ff ff j ff b j i K ff j b a ff ff ff b b St ff b ff ff b b ff b ff b St b j ff b ff j ff b j j b a ff ff ff b St ff b ff j ff ff b b j j b a ff

[a11] K a ff ji b ff ff St ff b ji j b K b j j j ff ff b ff ff ff ff ff b g b j

[a111] j j b j b j j St ff ff ff b b ff b ff j ff T j i ff ff ff b b ff T B B ff b j j i b St ff ff b b ff b ff T B ff ff b St b j i j ff T ff b b j St ff ff b j St b b ff j ff b ff b j j j j b ff

[a] j j b j b j j St ff ff ff b b ff b ff j ff T j i ff ff ff b b ff T B B ff b j j i b St ff ff b b ff b ff T B ff ff b St b j i j ff T ff b b j St ff ff b j St b b ff j ff b ff b j j j j b ff

[aa] j j b j b j j St ff ff ff b b ff b ff j ff T j i ff ff ff b b ff T B B ff b j j i b St ff ff b b ff b ff T B ff ff b St b j i j ff T ff b b j St ff ff b j St b b ff j ff b ff b j j j j b ff

[aa1] j j b j b j j St ff ff ff b b ff b ff j ff T

[aa11] j j b j b j j St ff ff ff b b ff b ff j ff T

[aa111] ff B B b b b b St ff ff ff b ff b St j i b ff j ff j ff b St ff ff ff b St ff b ff b ff B

[aa1] ff B St bi ff j j j ff j ff ff ff B ji b b ff

[aa] ff b B ff j g ff j b St ff b ff ff b ff ff j ff b bi ff b ff b j j ff j ff b ff b ff b ff T B ji b j j ff j j ff ff ff ff b b j j ff b b b ff ff ji b K b ff ff ff b b ji ff ff Stff ff B ff j g ff b ff ff ff b St ff b ff

[aa1] ff b j ff j St ff ff ff j ff T B ji b j

aa JJ J J bJb J J Stff ff ff b b ff b ff J ffT
aa JJJ J J bJb J J Stff ff ff b b ff b ff J ffT
aaa B jiJb K Sty b ffb bb b bJb ffb J St ffb Jff b JStbbff J ffOiJ B bbgff b bJK
b ff J ff ff ff ffff J Sty b ffb ff b St b ffTb ff ff ff b bJK
J ff ff b ji b J Jff b Tb ff ff ff b b bJK J ff ff bJK J ff b
StJ Jb ffa ffSt J bJK b ff St JffbJ b ff
aaa ffb OiJ B bbgff ff jgffJ b Stff b ff ff b ff ffJff b biff b ff bJ
J ffJff b biff St JffbJ ff b ff b ff T B ji bJ Jff J JffffJ ff ffb bJ J ff b
b b ff ff Stffb B ffOiJ B bbgff ff jgff b ff ff ff b Stff b ff
aaaJ jiiff ffff b jiiff J J J ff b ffJ Stff ff ff J ff T B Jb ffb J ff jiiffJib
jiiffJi JffffJ ff JJ ffB b i J ffb ffJff JiffaffbjiiffJSt St jiiffJi
ff ffff JStffB b i J ffb ffJff JSt J ff
aaaJJ jiiff ffff b jiiff J J J ff b ffJ Stff ff ff J ff T B Jb ffb J ff jiiffJib
jiiffJi JffffJ ff JJ ffB b i J ffb ffJff JiffaffbjiiffJSt St
jiiffJi ff ffff JStffB b i J ffb ffJff JSt J ff
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jiiffJi JffffJ ff JJ ffB b i J ffb ffJff JiffaffbjiiffJSt St
jiiffJi ff ffff JStffB b i J ffb ffJff JSt J ff
aaaJ J J bJb J J Stff ff ff b b ff b ff J ffT Ji ff ffff bb ff T B B ff b JJi
b Stffff bb ff b ff T B ffff b St bJiJ ffT ff bbJ St ff ff b JStbbff JffbffJ
b JJJ J b ff
aaa J J bJb J J Stff ff ff b b ff b ff J ffT
aaaJB jiJb K Sty b ffb bb b bJb ffb J St ffb Jff b JStbbff J ffOiJ B bbgff b bJK
b ff J ff ff ff ffff J Sty b ffb ff b St b ffTb ff ff ff b bJK
J ff ff b ji b J Jff b Tb ff ff ff b b bJK J ff ff bJK J ff b
StJ Jb ffa ffSt J bJK b ff St JffbJ b ff
aaaJJ ffb J ffJ Stff ff ff J ff T B ji bJ
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J ffJff b biff St JffbJ ff b ff b ff T B ji bJ Jff J JffffJ ff ffb bJ J ff b
b b ff ff Stffb B ffTb ff ff ff b ff jgff b ff ff ff b Stff b ff
aaaaJ J J bJb J J Stff ff ff b b ff b ff J ffT
a J J bJb J J Stff ff ff b b ff b ff J ffT
aJB jiJb K Sty b ffb bb b bJb ffb J St ffb Jff b JStbbff J ffOiJ B bbgff b bJK b ff
J ff ff ff ffff J Sty b ffb ff b St b ffTb ff ff ff b bJK J ff ff b
ji b J Jff b Tb ff ff ff b b bJK J ff ff bJK J ff b StJ Jb ffa ffSt J bJK
b ff St JffbJ b ff
aJJ J J bJb J J Stff ff ff b b ff b ff J ffT
aJJJ J J bJb J J Stff ff ff b b ff b ff J ffT
aJ ff ff B bbgff J ff J b ff ff B b i St B b ff b B b iK St Stff b b ff
ff ff ff J b ji b ff J ff ji ff b ff ff ff Stff JiJ ff B b ff
Stff ff ff Stff B bbgff b ff ff b b ff ff ji b Stff JiJ ff ff ff
B bbgff J ff b b ff
a J J bJb J J Stff ff ff b b ff b ff J ffT
aJ J J bJb J J Stff ff ff b b ff b ff J ffT
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J ff Stff ff B bbgff Stff B bbgff ff J b ji ff Stff JiJ ff b ff ff b
b ff ff ji b Stff JiJ ff ff ff ff J ff J b ff
aaJ J J bJb J J Stff ff ff b b ff b ff J ffT
J J bJb J J Stff ff ff b b ff b ff J ffT
J ff Stff B bbgff J ff J b ff ff B b iK St Stff b b ff ff ff Stff Ji J ff
b ff J ff Stff ff B bbgff ff ff ff J b ji ff Stff JiJ ff b ff ff
b b ff ff ji b Stff JiJ ff ff Stff B bbgff J ff b b ff
JJ J J bJb J J Stff ff ff b b ff b ff J ffT
JJJ J J bJb J J Stff ff ff b b ff b ff J ffT
J J J bJb J J Stff ff ff b b ff b ff J ffT
J J bJb J J Stff ff ff b b ff b ff J ffT