Analog Input 2-wire 4-20mA Transmitters

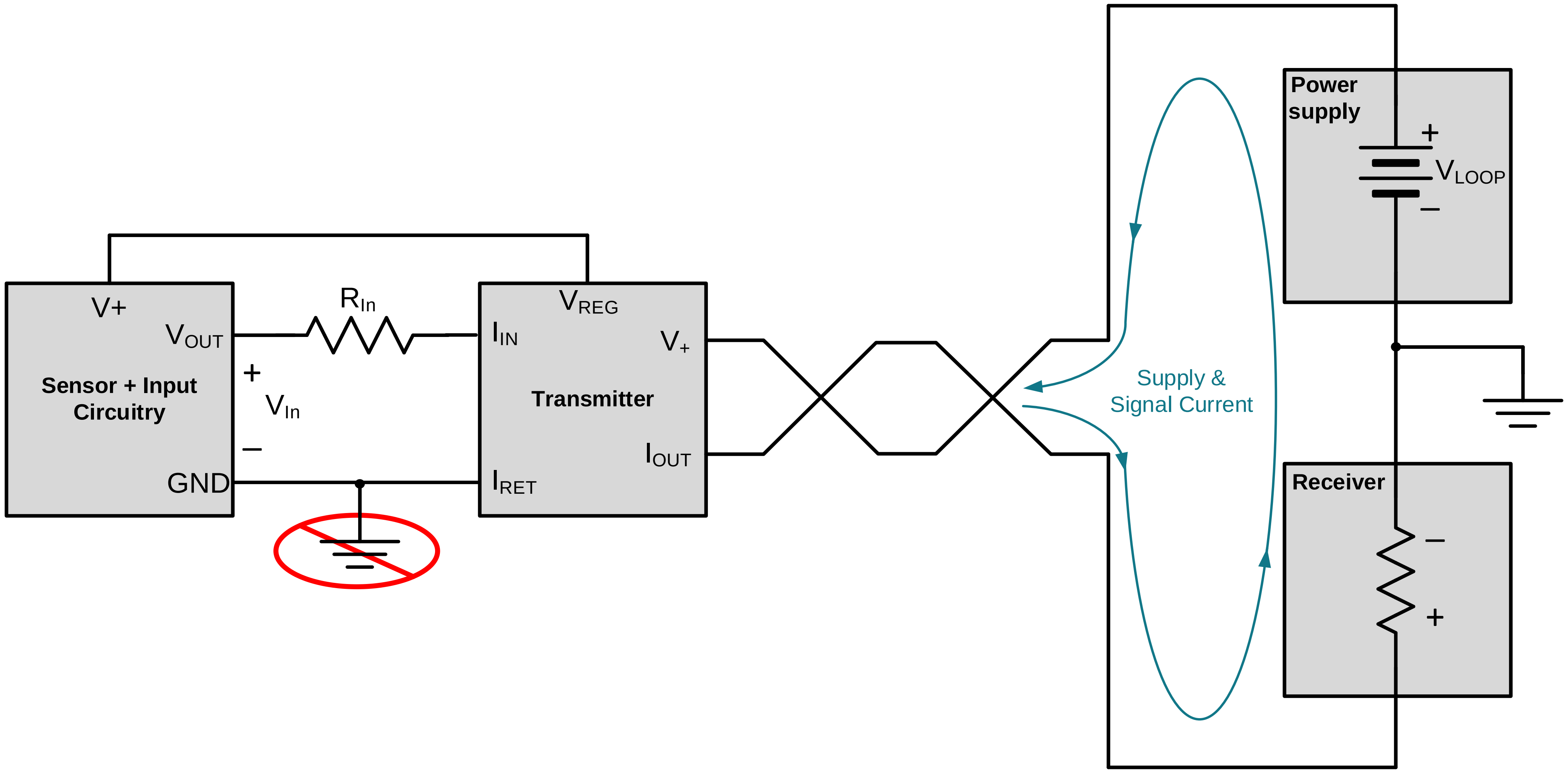
TI Precision Labs – Current Loop Transmitters

Presented by Katlynne Jones

Prepared by Katlynne Jones

2-wire transmitter

- 2-wire transmitter block diagram
  - 2 wires create a loop that transmits the signal current and transmitter power
  - I_{RET} cannot be grounded to V_{LOOP}!
  - Transmitter, sensor, and input circuitry must consume <4mA



Derivation of transfer function

$$V_+ = V_-$$

$$I_{IN} = \left(\frac{V_{DAC}}{R_{IN}} + \frac{V_{REG}}{R_{OS}}\right)$$

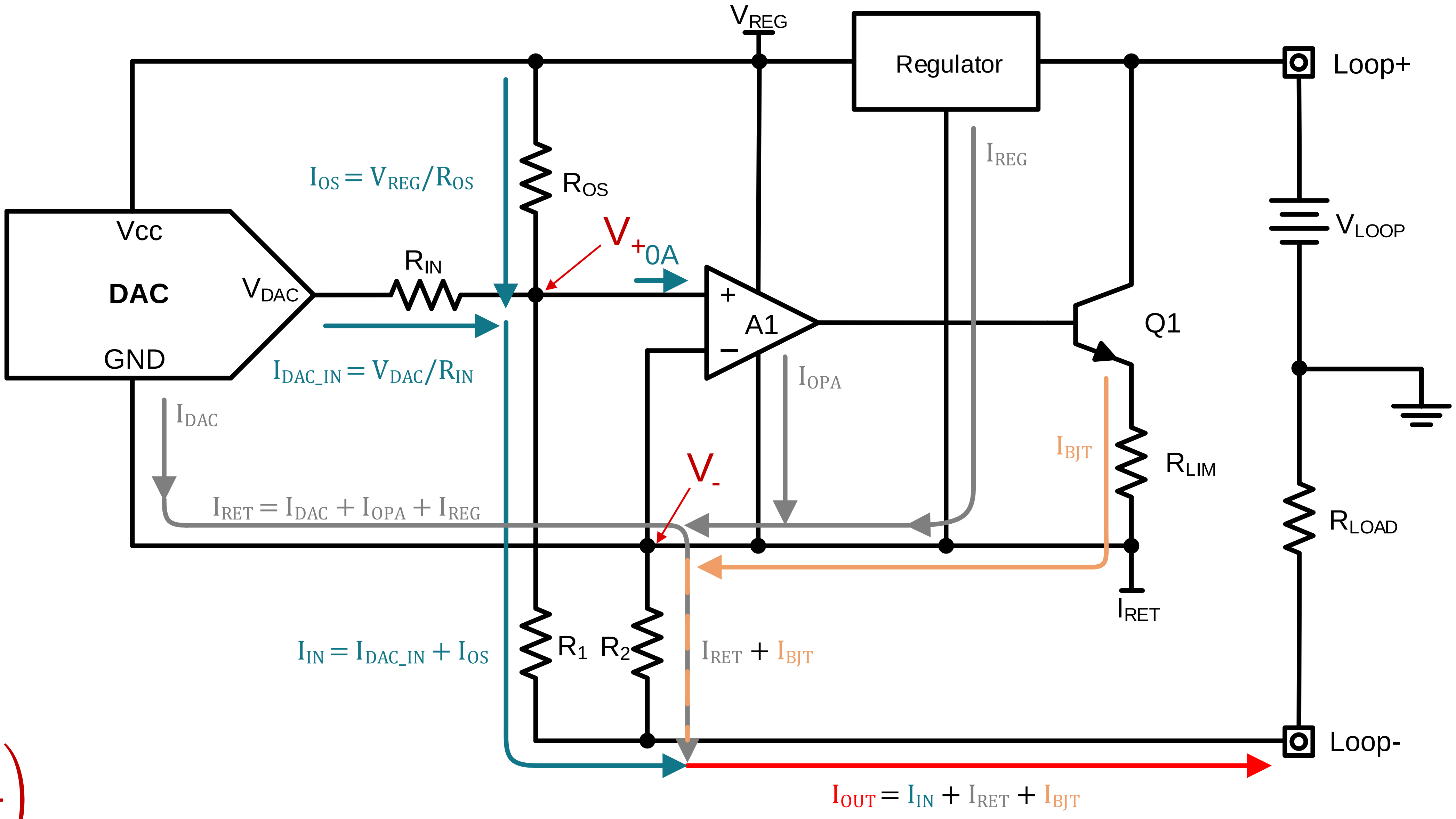
$$V_+ = I_{IN} * R_1$$

$$V_- = (I_{RET} + I_{BJT}) * R_2$$

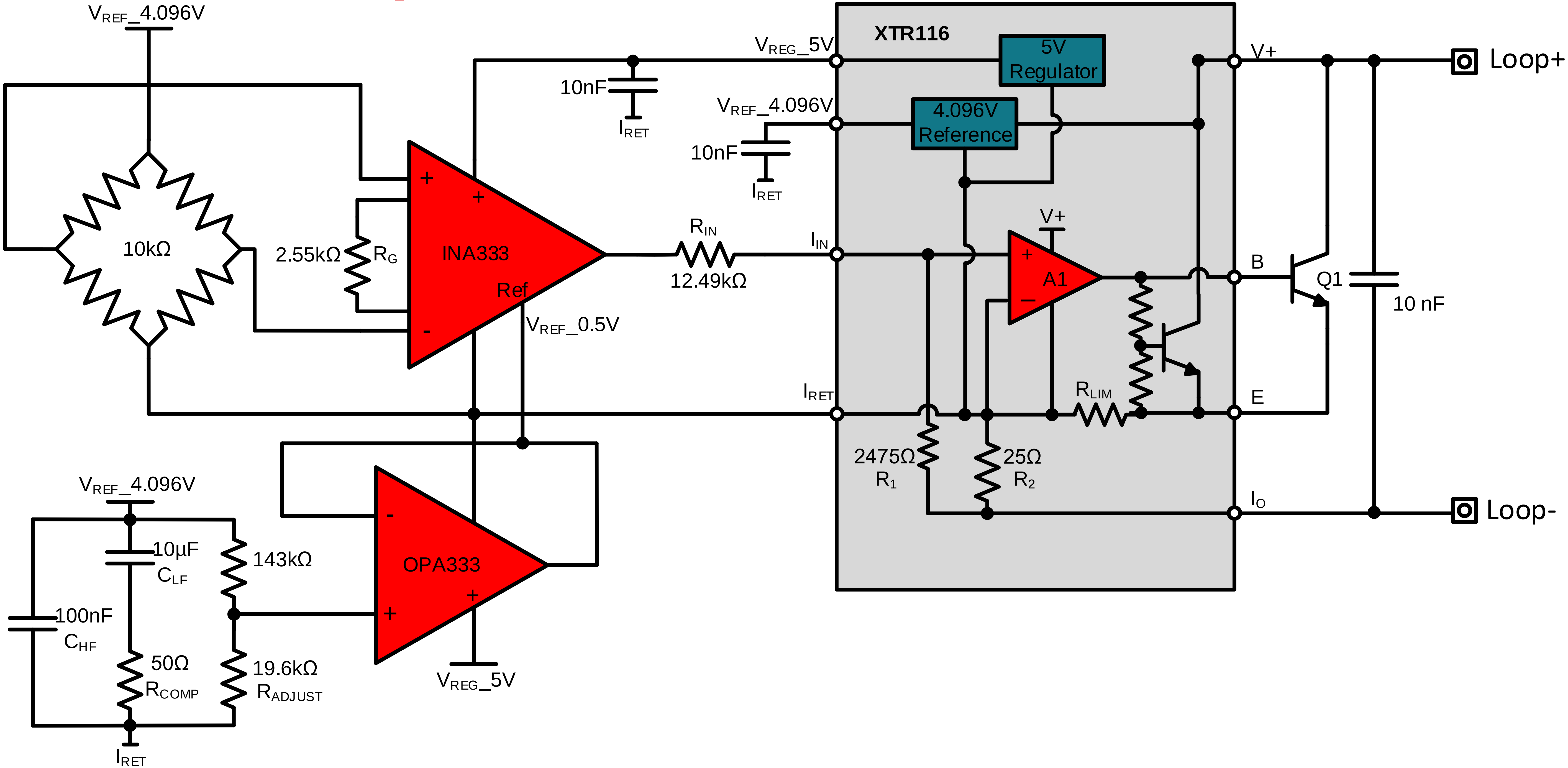
$$I_{IN} * R_1 = (I_{RET} + I_{BJT}) * R_2$$

$$I_{BJT} + I_{RET} = \frac{I_{IN} * R_1}{R_2}$$

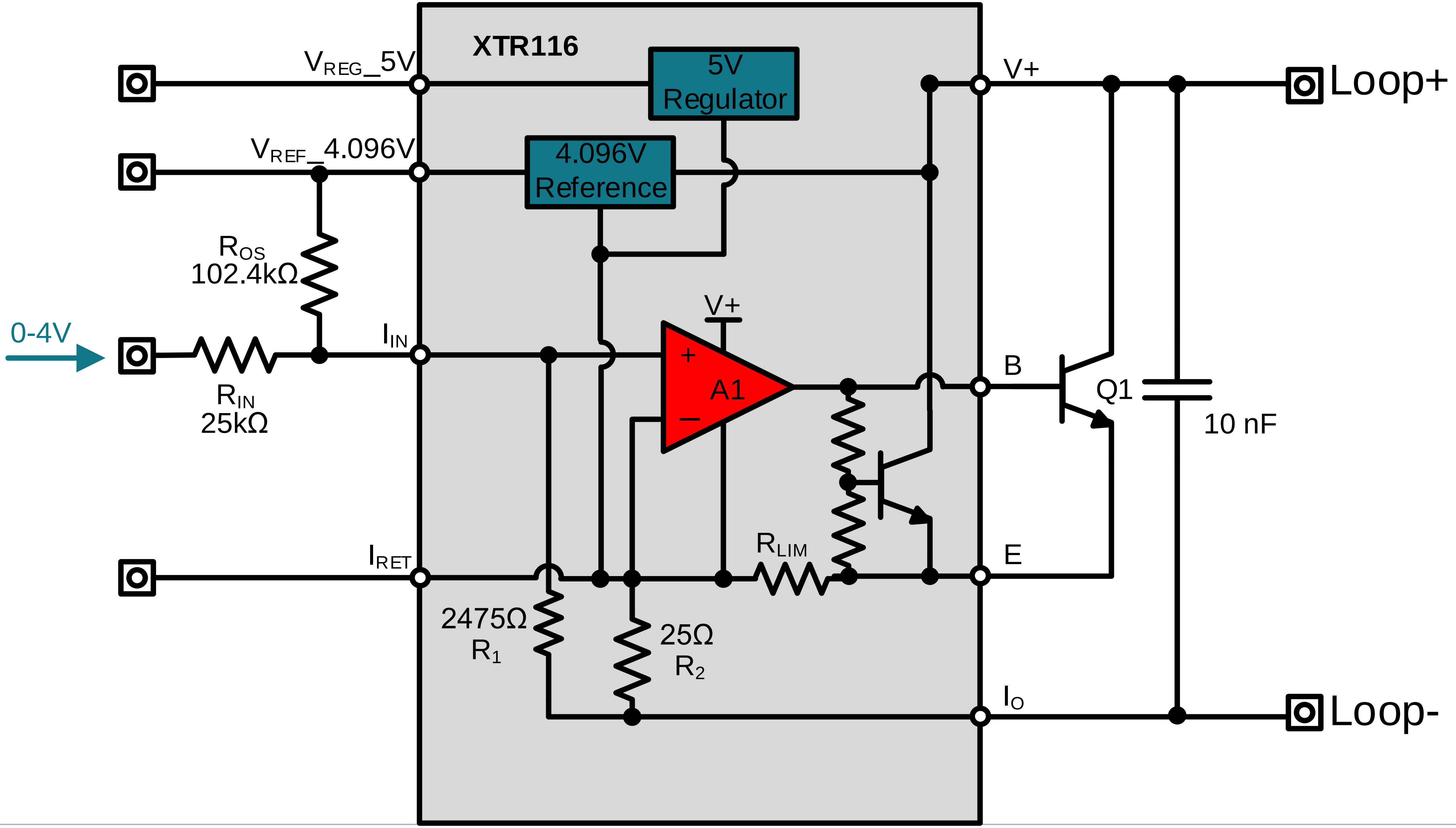
$$I_{OUT} = \left(\frac{V_{DAC}}{R_{IN}} + \frac{V_{REG}}{R_{OS}}\right) * \left(1 + \frac{R_1}{R_2}\right)$$



Transmitter input



Transmitter input



I_{RET}

$$I_{IN} = \left(I_{SOURCE} + \frac{V_{REF}}{R_{OS}}\right)$$

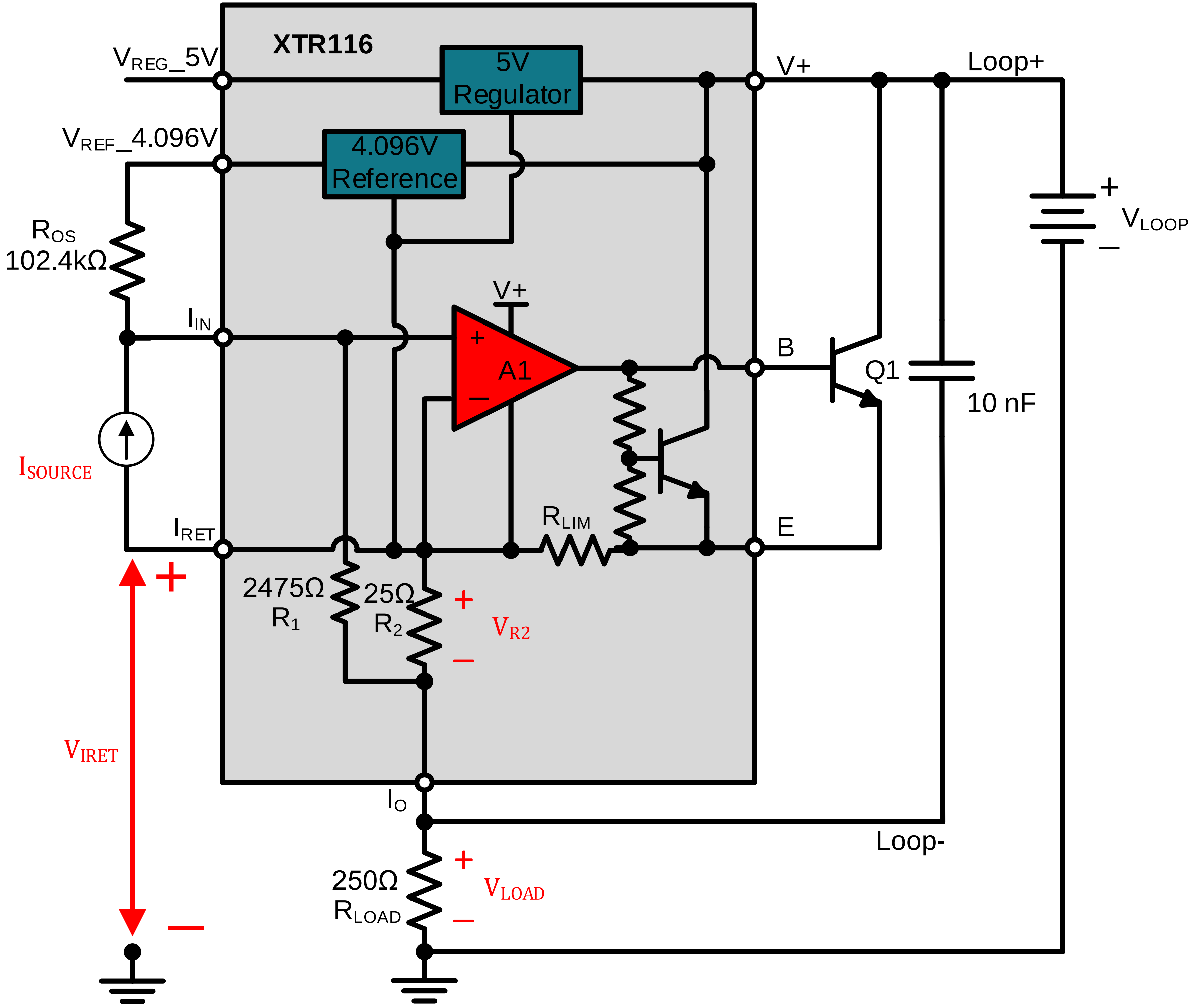
$$I_{OUT} = \left(I_{SOURCE} + \frac{V_{REF}}{R_{OS}}\right) * \left(1 + \frac{R_1}{R_2}\right)$$

$$V_{LOAD} = I_{OUT} * R_{LOAD}$$

$$V_+ = V_- = V_{R1} = V_{R2}$$

$$V_+ = V_{R2} = I_{IN} * R_1$$

$$V_{IRET} = V_{R2} + V_{LOAD}$$



I_{RET}

$$I_{IN} = \left(I_{SOURCE} + \frac{V_{REF}}{R_{OS}}\right)$$

$$I_{IN} = \left(0A + \frac{4.096V}{102.4k\Omega}\right) = 40\mu A$$

$$I_{OUT} = \left(I_{SOURCE} + \frac{V_{REF}}{R_{OS}}\right) * \left(1 + \frac{R_1}{R_2}\right)$$

$$I_{OUT} = (40\mu A) * \left(1 + \frac{2475\Omega}{25\Omega}\right) = 4mA$$

$$V_{LOAD} = I_{OUT} * R_{LOAD}$$

$$V_{LOAD} = 4mA * 250\Omega = 1V$$

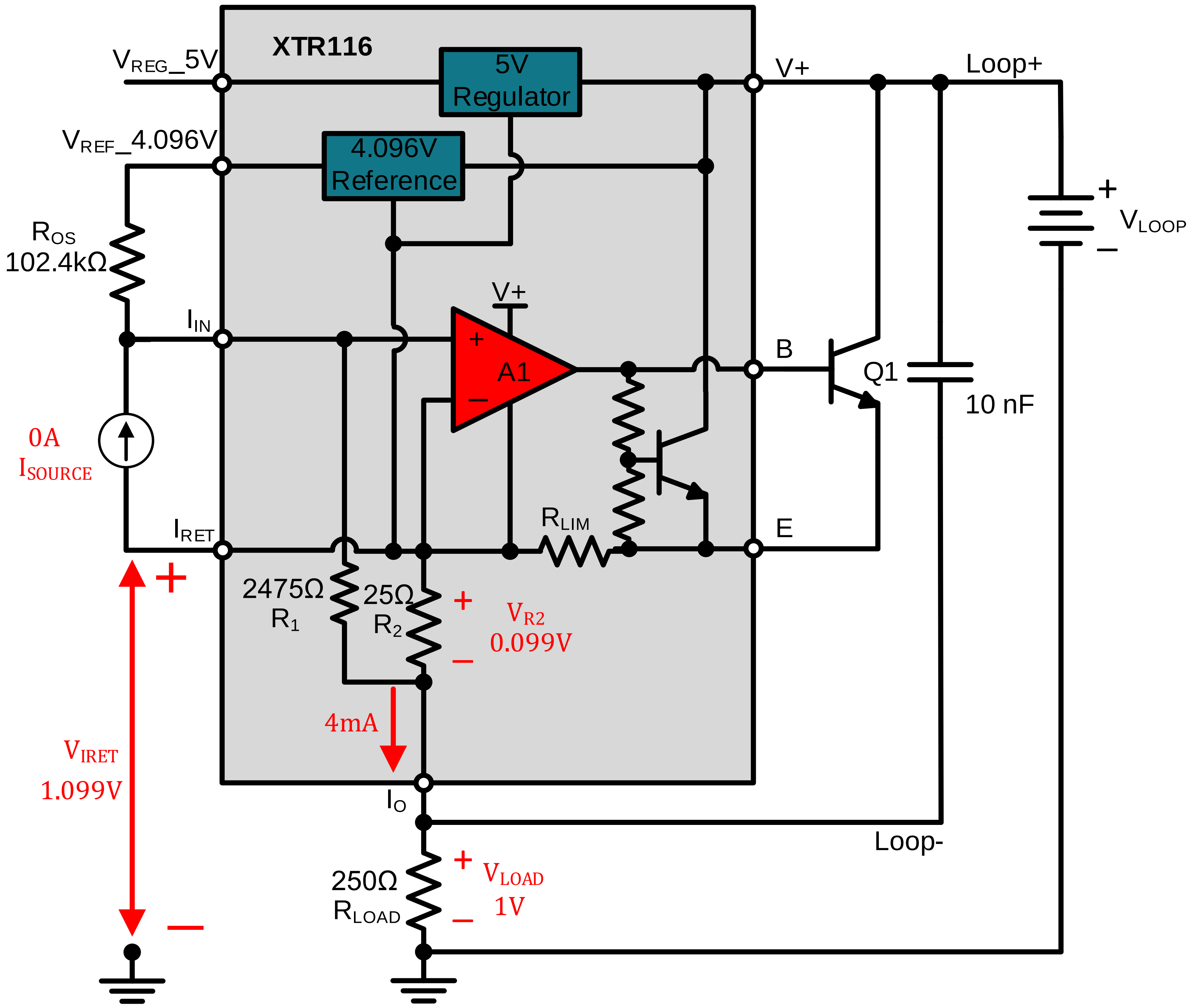
$$V_+ = V_- = V_{R1} = V_{R2}$$

$$V_+ = V_{R2} = I_{IN} * R_1$$

$$V_{R2} = 40\mu A * 2475\Omega = 0.099V$$

$$V_{IRET} = V_{R2} + V_{LOAD}$$

$$V_{IRET} = 0.099V + 1V = 1.099V$$



I_{RET}

$$I_{IN} = \left(I_{SOURCE} + \frac{V_{REF}}{R_{OS}}\right)$$

$$I_{IN} = \left(160\mu A + \frac{4.096V}{102.4k\Omega}\right) = 200\mu A$$

$$I_{OUT} = \left(I_{SOURCE} + \frac{V_{REF}}{R_{OS}}\right) * \left(1 + \frac{R_1}{R_2}\right)$$

$$I_{OUT} = (200\mu A) * \left(1 + \frac{2475\Omega}{25\Omega}\right) = 20mA$$

$$V_{LOAD} = I_{OUT} * R_{LOAD}$$

$$V_{LOAD} = 20mA * 250\Omega = 5V$$

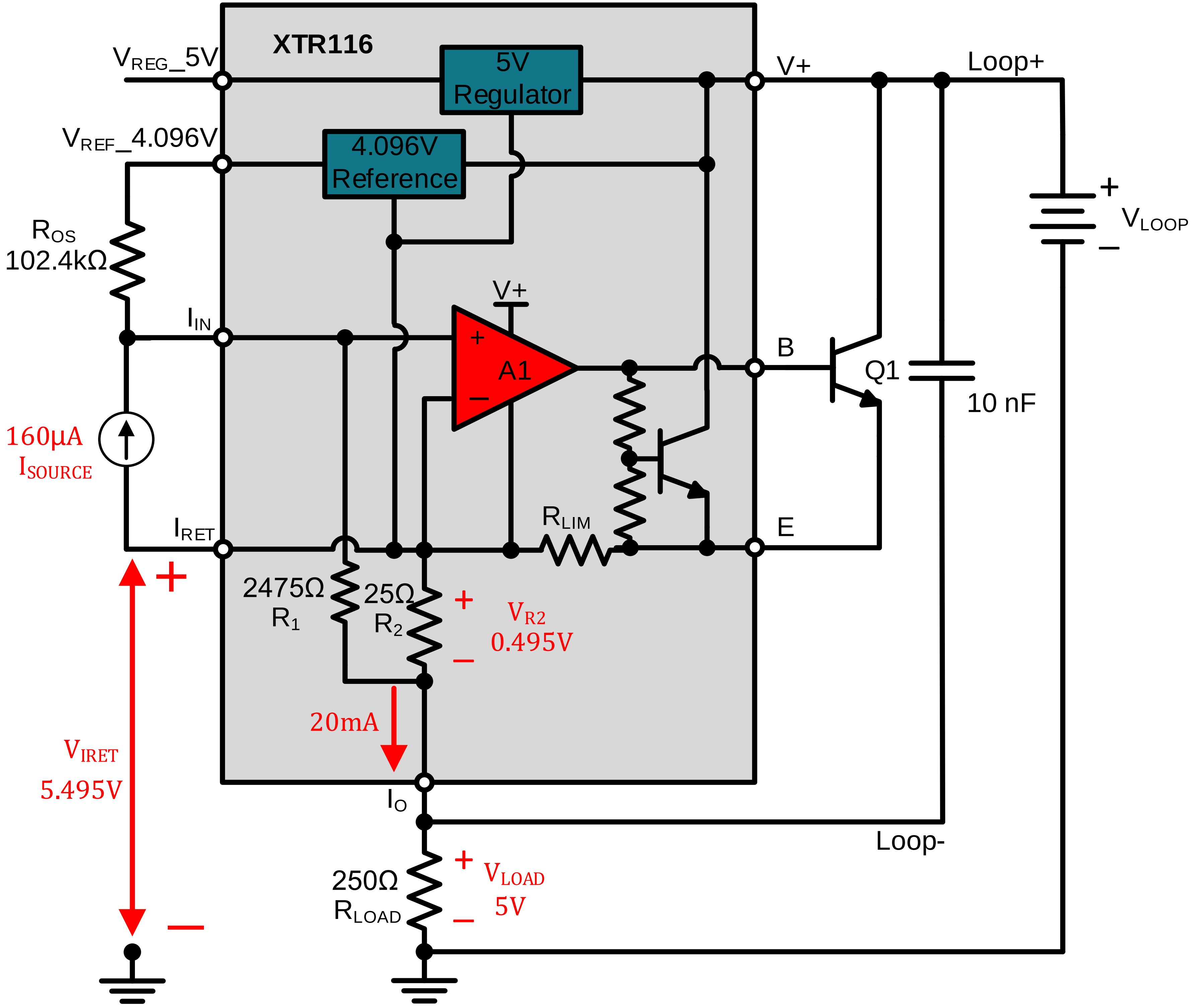
$$V_{+} = V_{-} = V_{R1} = V_{R2}$$

$$V_{+} = V_{R2} = I_{IN} * R_1$$

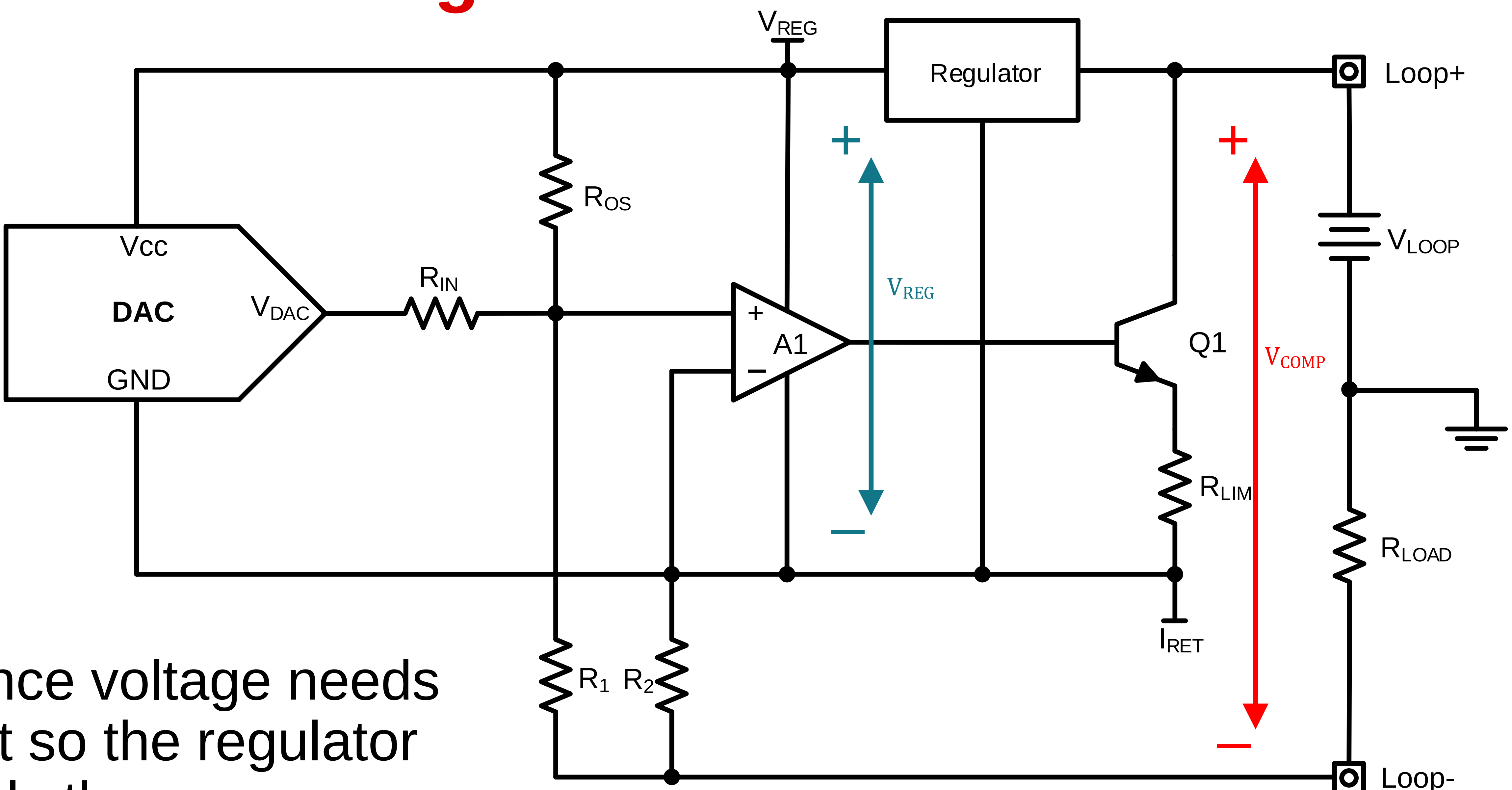
$$V_{R2} = 200\mu A * 2475\Omega = 0.495V$$

$$V_{IRET} = V_{R2} + V_{LOAD}$$

$$V_{IRET} = 0.495V + 5V = 5.495V$$

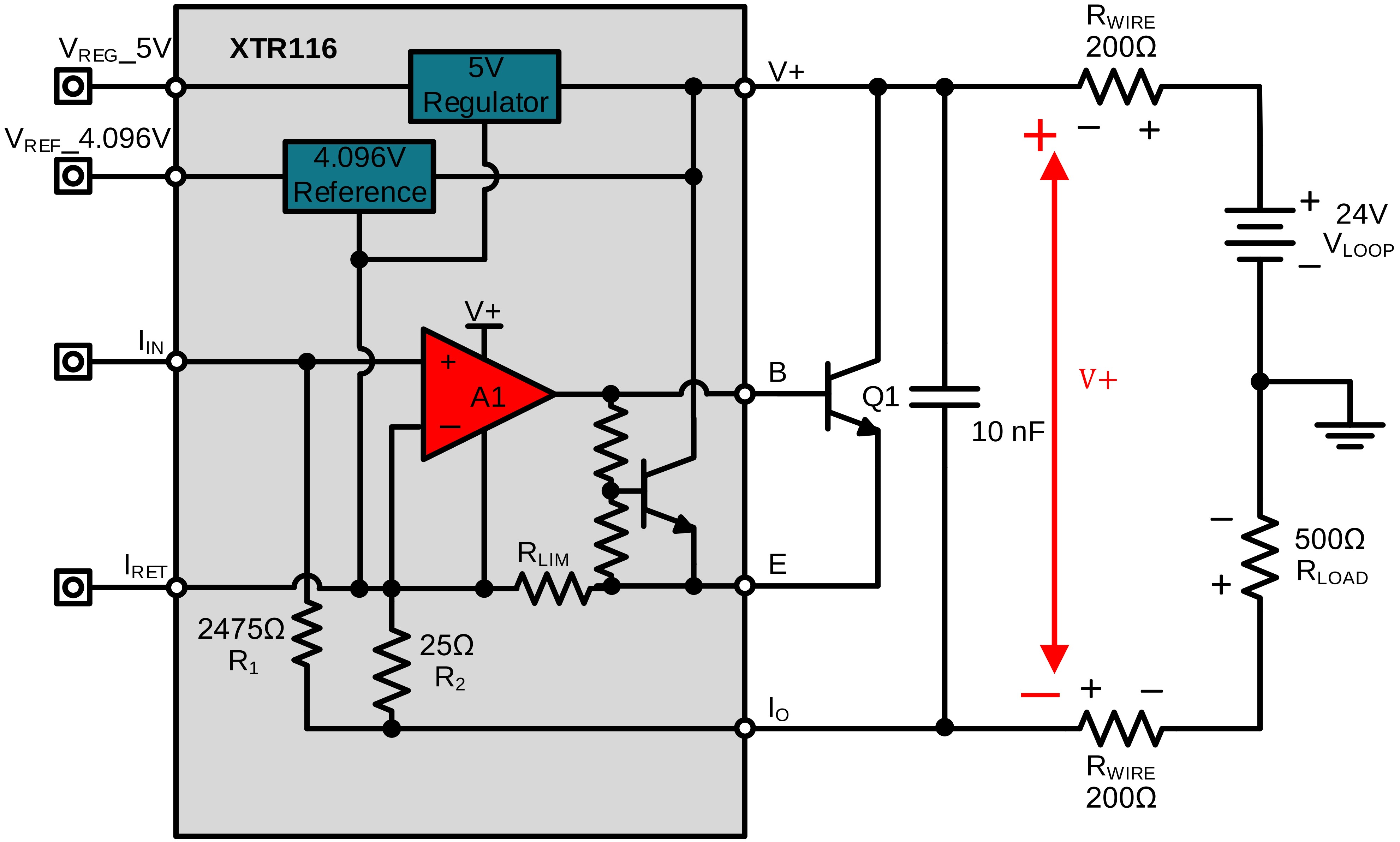


Compliance voltage



Compliance voltage needs to be met so the regulator can supply the op amp with enough voltage.

Compliance voltage



$$V_{LOOP} \geq V_{COMP} + I_{OUT\_MAX} * R_{MAX}$$

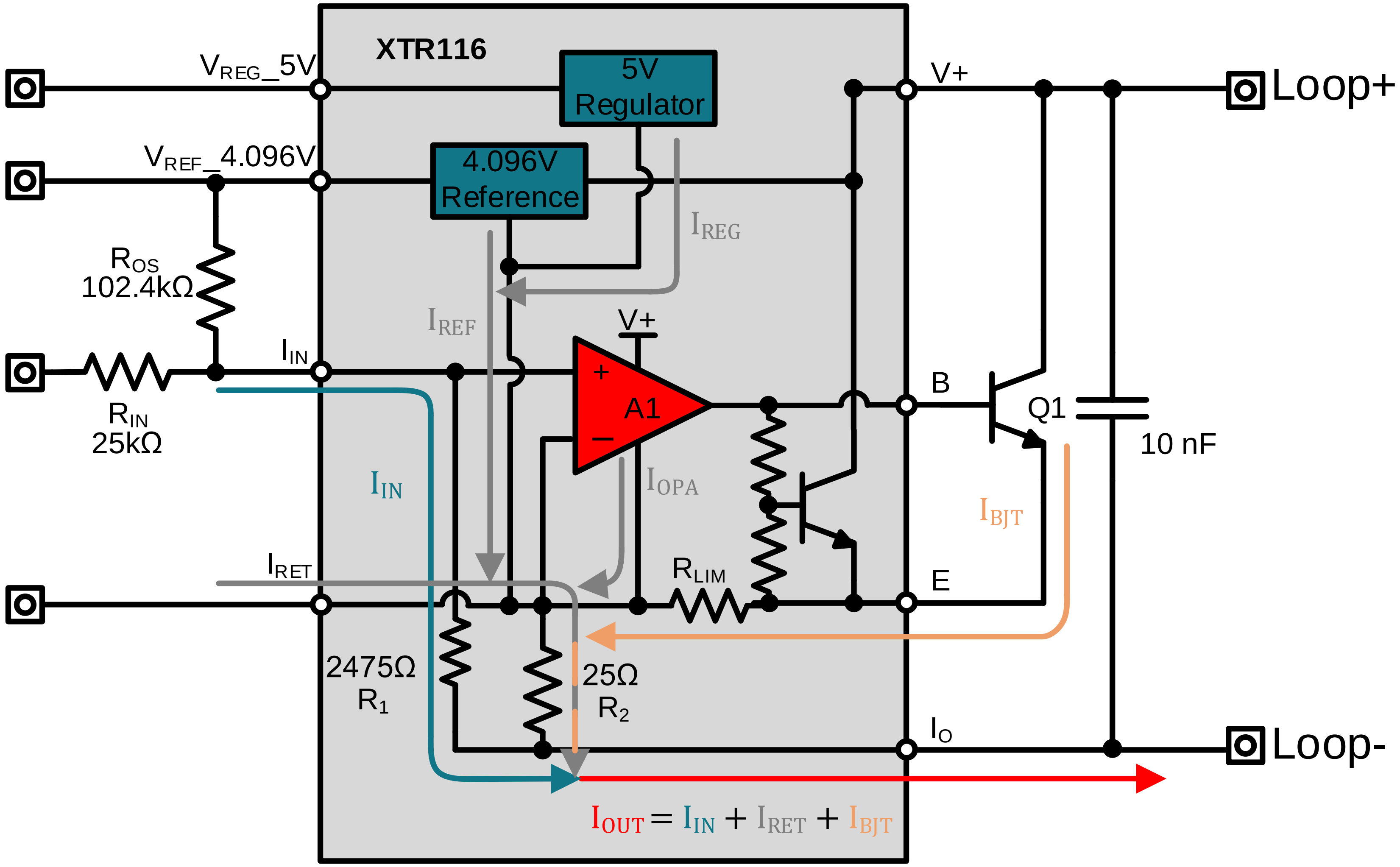
$$V_{+} = V_{LOOP} - I_{OUT\_MAX} * R$$

$$V_{+} = 24V - 20mA * 900\Omega = 6V$$

$$R_{MAX} = \frac{V_{LOOP} - V_{COMP}}{I_{OUT\_MAX}}$$

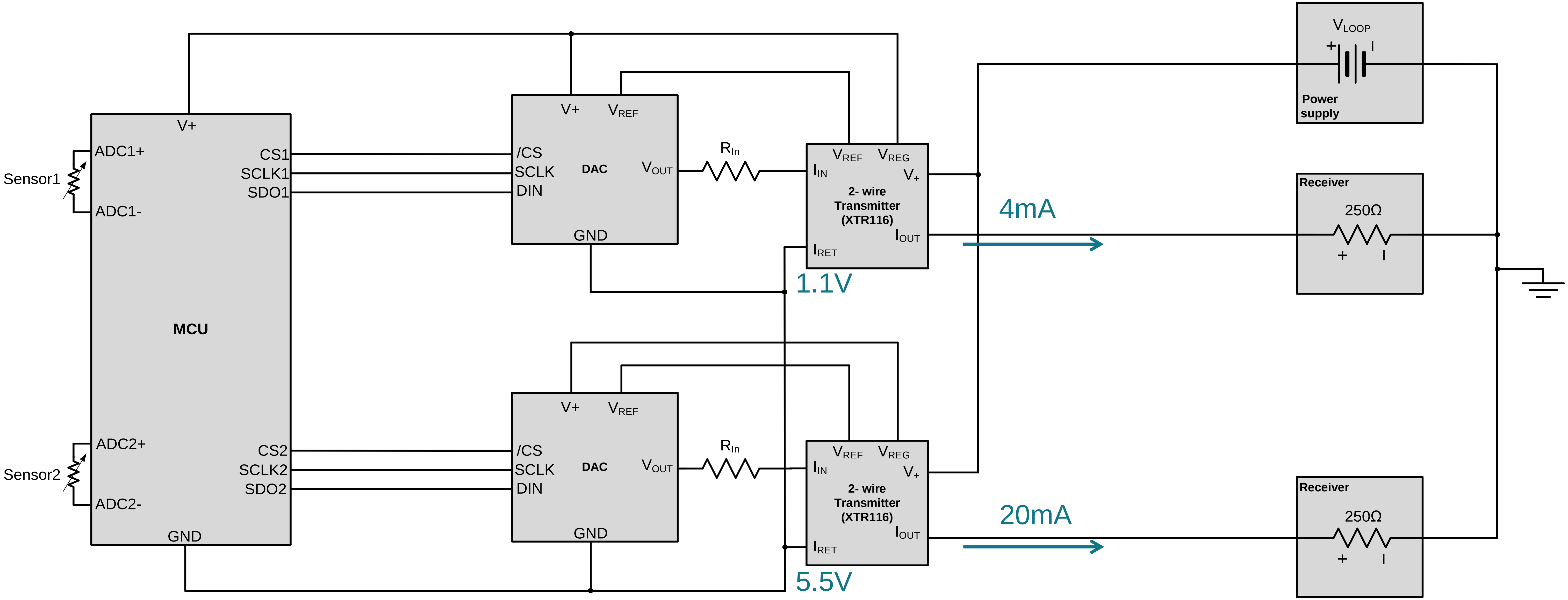
$$R_{MAX} = \frac{24V - 7.5V}{20mA} = 825\Omega$$

4mA Current budget



POWER SUPPLY			MIN	TYP	MAX	
Specified Voltage Range	V+			+24		V
Operating Voltage Range			+7.5		+40	V
Quiescent Current	I_Q			130	200	µA
Over Temperature		**T_A = –40°C to +125°C**			**250**	**µA**

Input isolation



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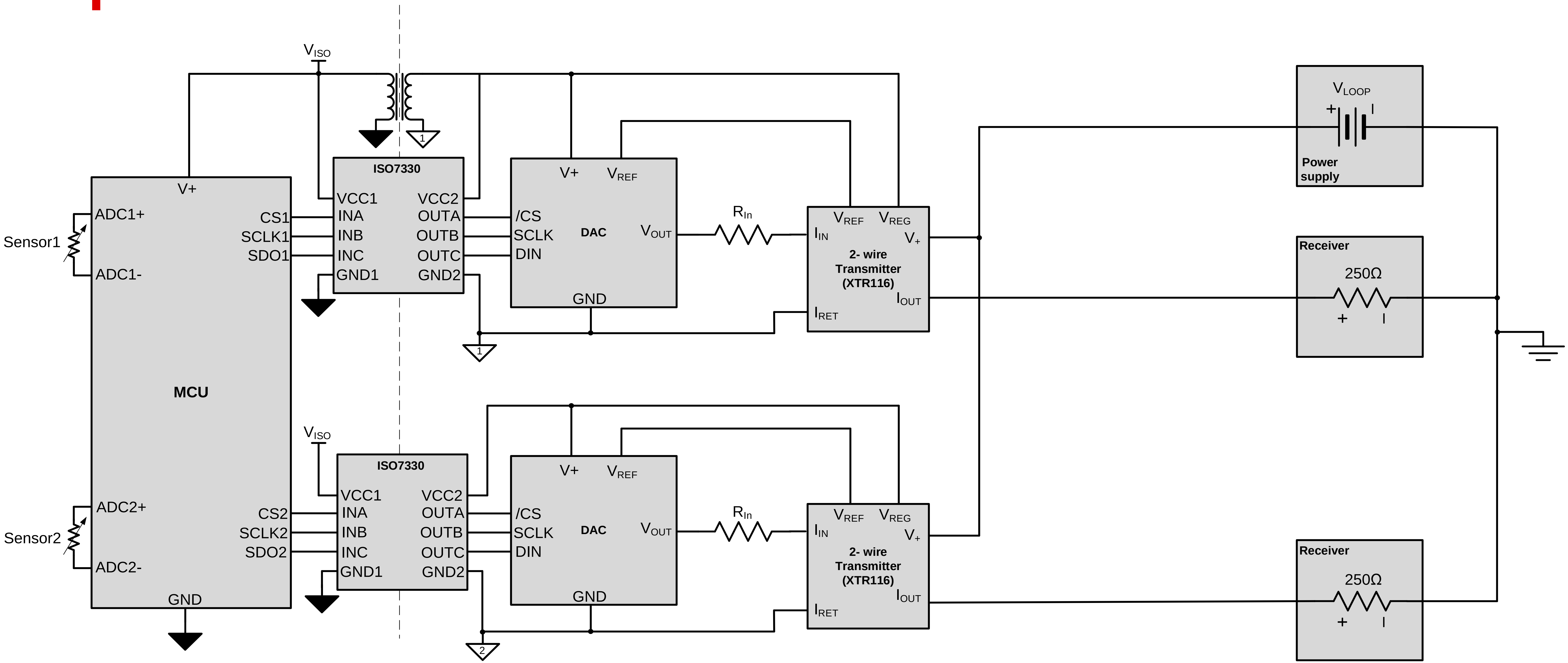

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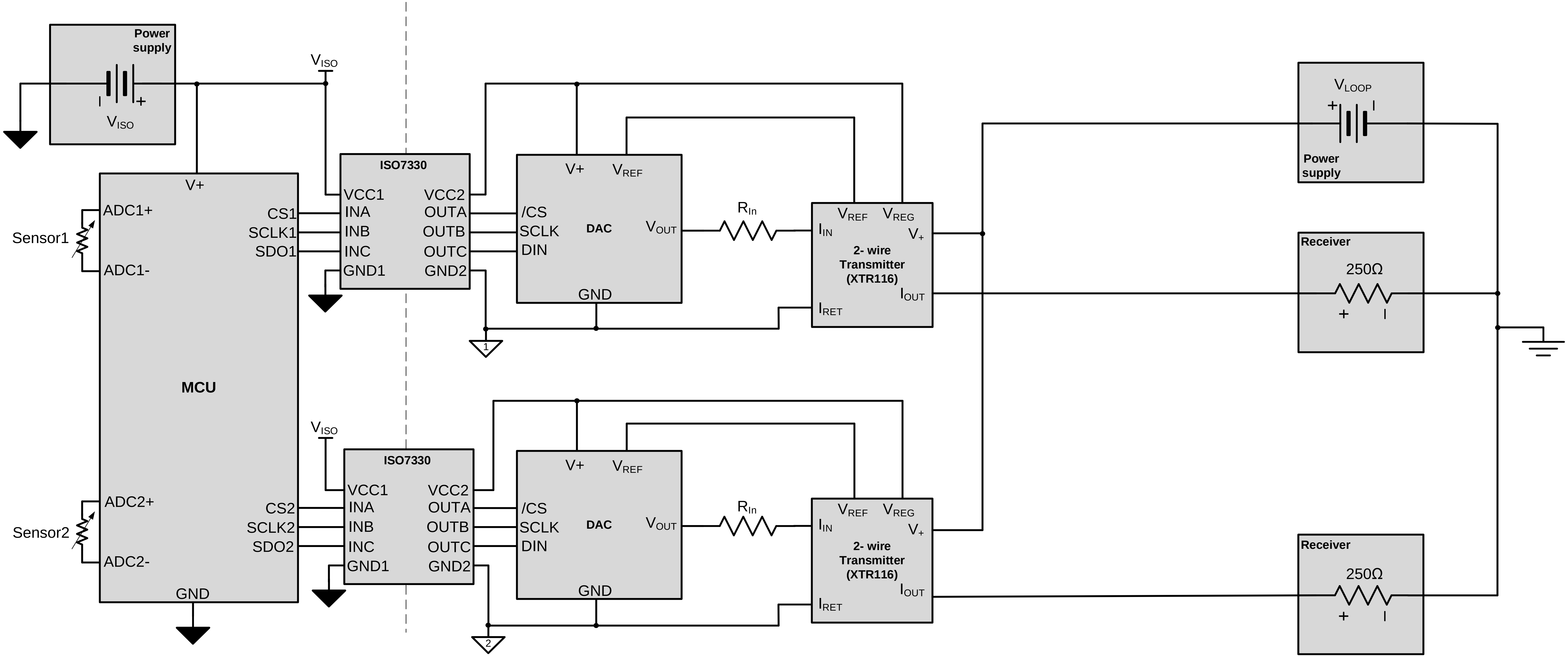

XTR parts

Part	Description	Loop Voltage (V)	Full-Scale Input Range	Reference	Regulator	Gain
XTR101	IA + Current Excitation	11.6-40	Settable	Current reference	-	Settable
XTR115	IIN to IOUT Converter. External Resistor Scales VIN to IIN	7.5-36	40µA to 200µA	2.5V	5V	100A/A
XTR116	IIN to IOUT Converter. External Resistor Scales VIN to IIN	7.5-36	40µA to 200µA	4.096V	5V	100A/A
XTR117	IIN to IOUT Converter. External Resistor Scales VIN to IIN	7.5-40	40µA to 200µA	-	5V	100A/A

XTR parts

Part	Description	Sensor Excitation	Loop Voltage (V)	Nonlinearity Correction	Regulator	Gain
XTR105	100Ω RTD Conditioner	Two 800µA	7.5-36	40:1 improvement	5.1V	Settable
XTR112	1kΩ RTD Conditioner	Two 250µA	7.5-36	40:1 improvement	5.1V	Settable
XTR106	Bridge Conditioner	5V and 2.5V	7.5-36	20:1 improvement	5.1V	Settable
XTR108	Smart Programmable RTD or Bridge Conditioner	Settable	7.5-36	40:1 improvement	5.1V	Settable

Thanks for your time!
Please try the quiz.

To find more Current Transmitter technical resources and search products, visit: www.ti.com/amplifier-circuit/special-function/4-20ma-signal-conditioners.html

Quiz: 2-wire 4-20mA Transmitters

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Quiz: 2-wire 4-20mA Transmitters || Question

1. Which statement about a 2-wire transmitter is false?

   a) The transmitter, sensor, and input circuitry must consume less than 4mA of current
   b) I_{RET} cannot be grounded to V_{LOOP}
   c) Input isolation can be used to connect multiple 2-wire transmitters in parallel
   d) The V_{LOOP} voltage needs to be greater than the compliance voltage

Quiz: 2-wire 4-20mA Transmitters || Answer

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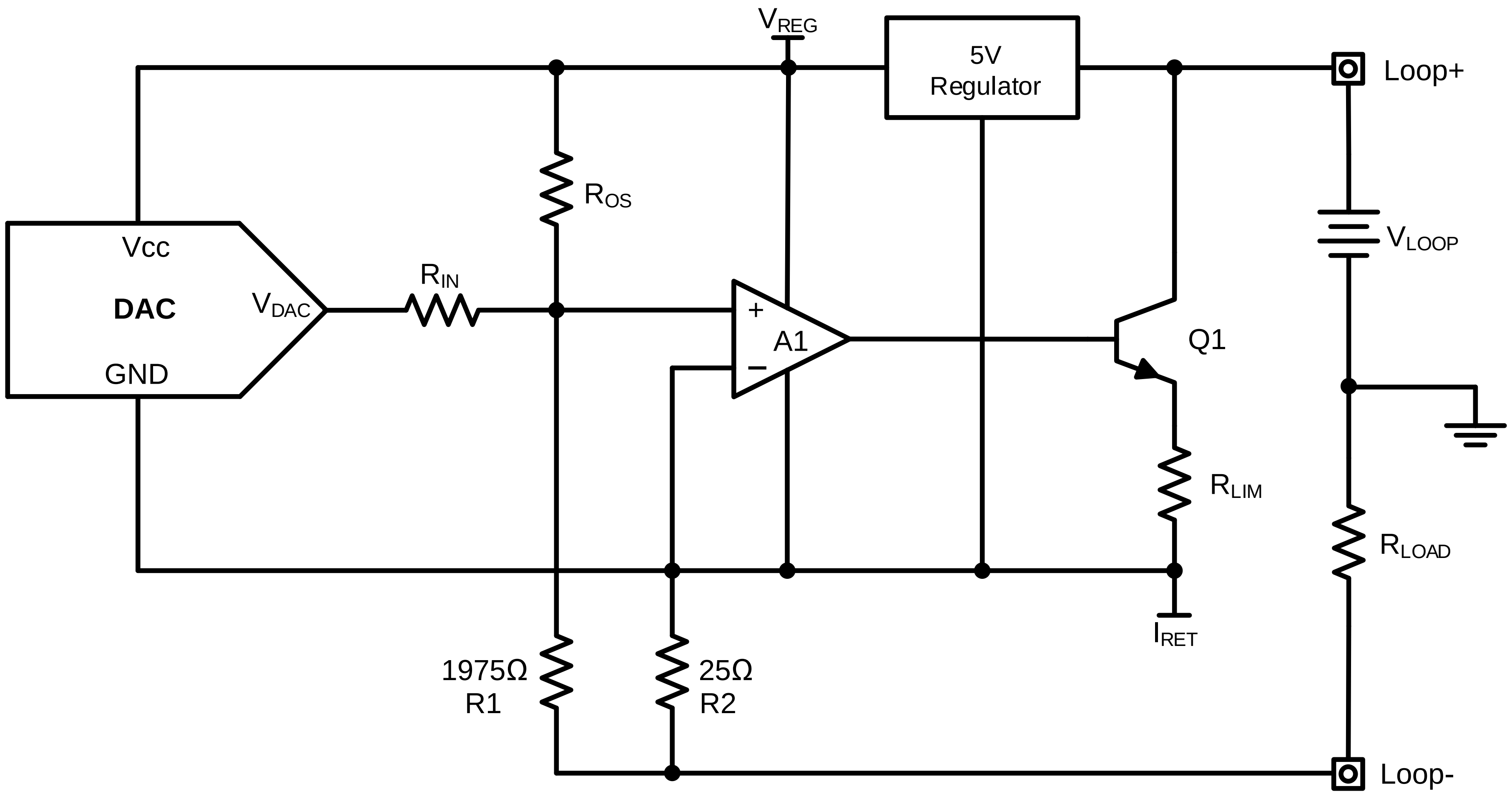
Quiz: 2-wire 4-20mA Transmitters || Question

2. Given the 2-wire transmitter below, what is the gain of the transmitter if R1 is 1975Ω and R2 is 25Ω?

a) 10
b) 40
c) 80
d) 100



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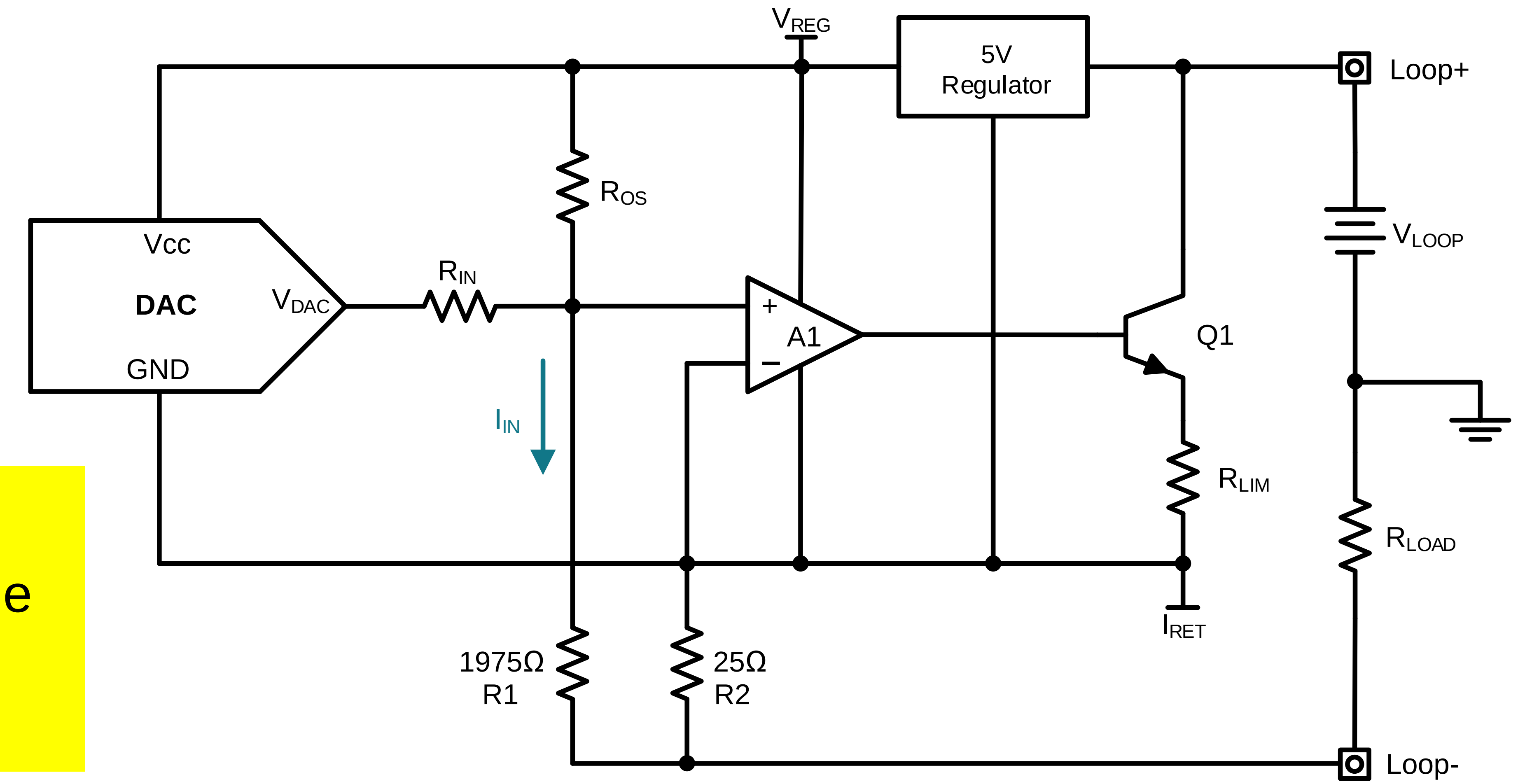
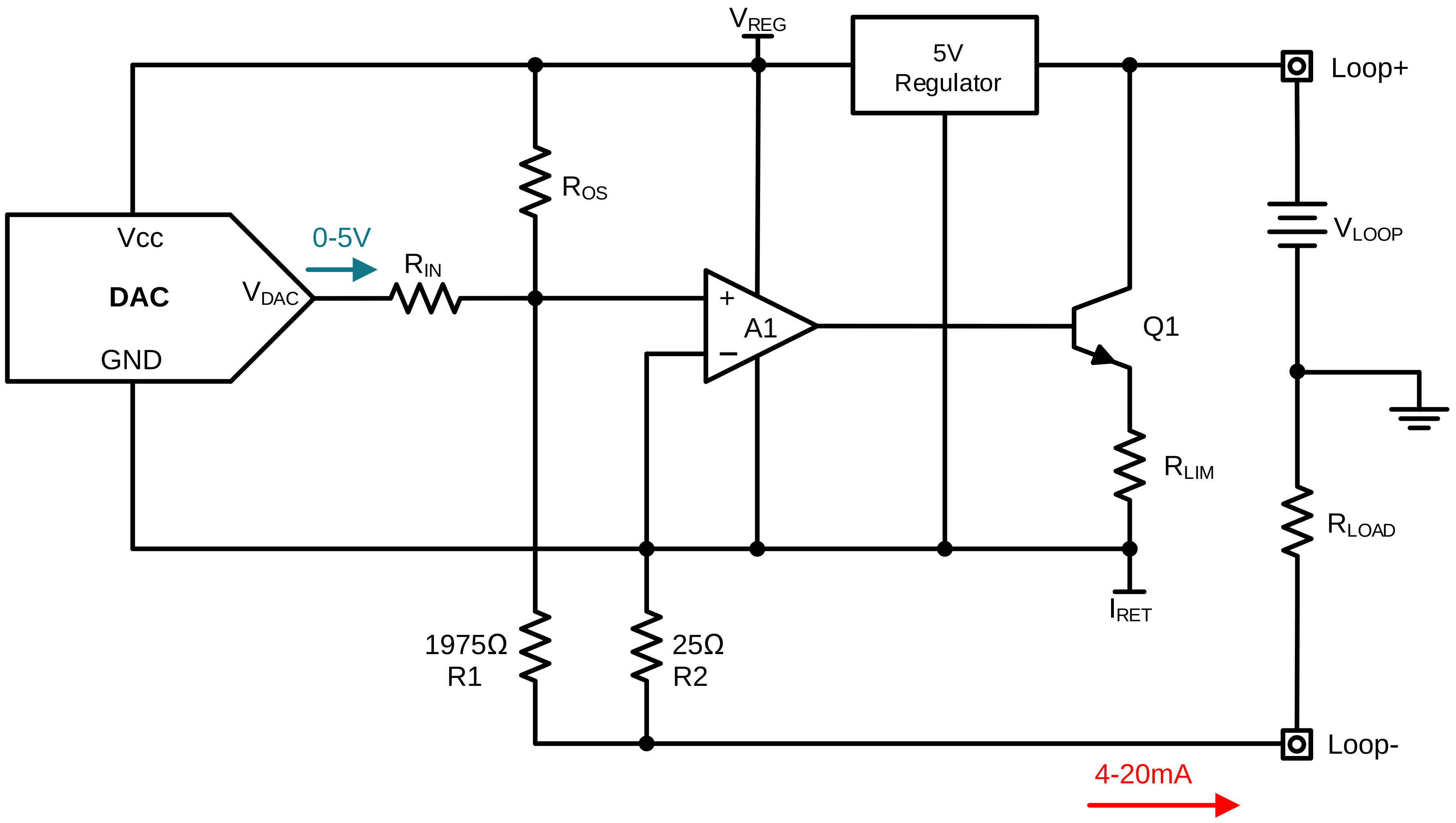


The transfer function of this 2-wire transmitter is $I_{OUT} = I_{IN} * \left(1 + \frac{R_1}{R_2}\right)$. The gain is defined by $\left(1 + \frac{R_1}{R_2}\right)$.

Quiz: 2-wire 4-20mA Transmitters || Question

3. Given the 2-wire transmitter below, what value for R_{IN} and R_{OS} should be chosen to get an output of 4-20mA with V_{DAC} voltage of 0-5V?

a) 5kΩ and 75kΩ
b) 25kΩ and 100kΩ
c) 30kΩ and 125kΩ
d) 50kΩ and 150kΩ



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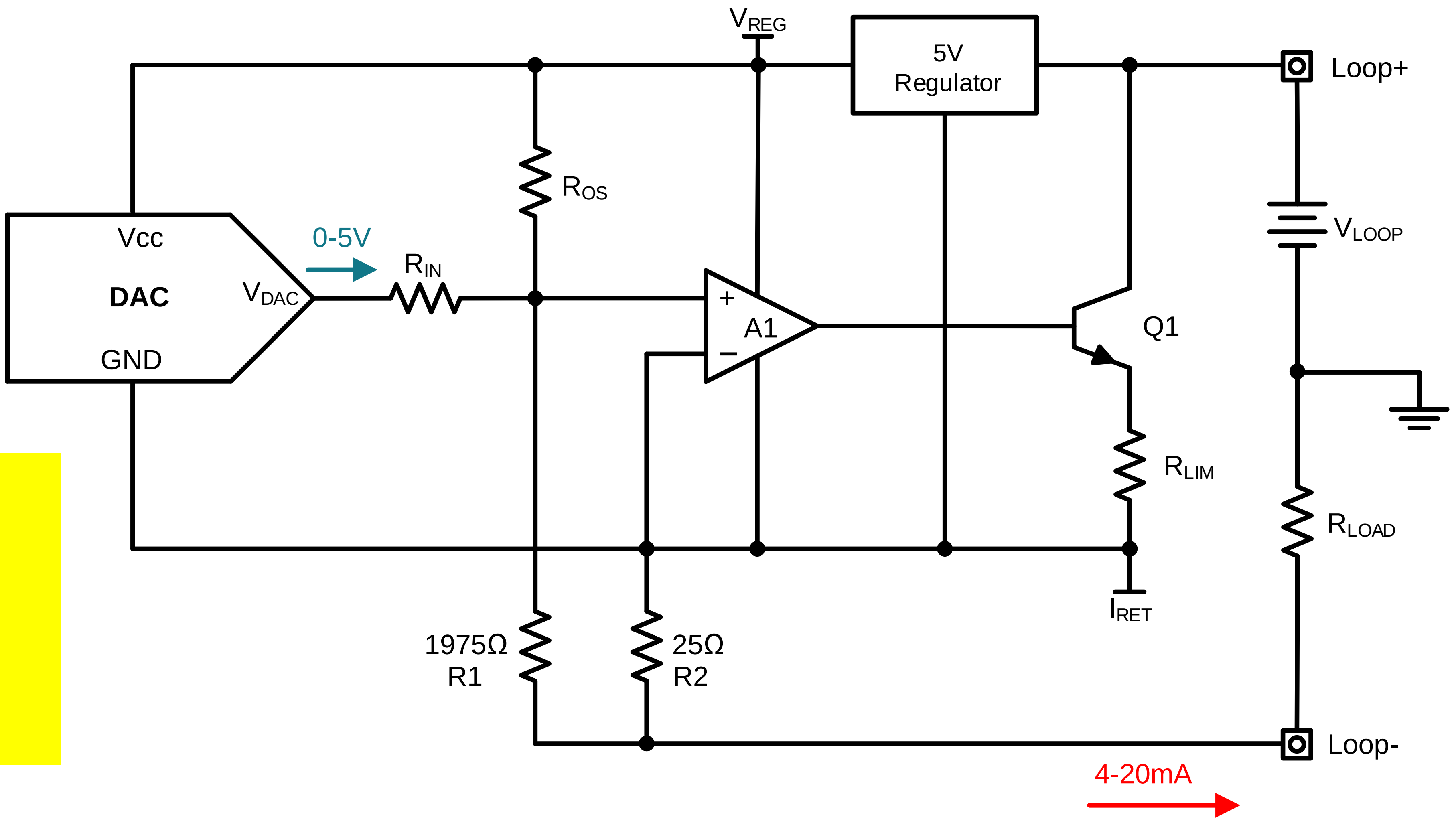
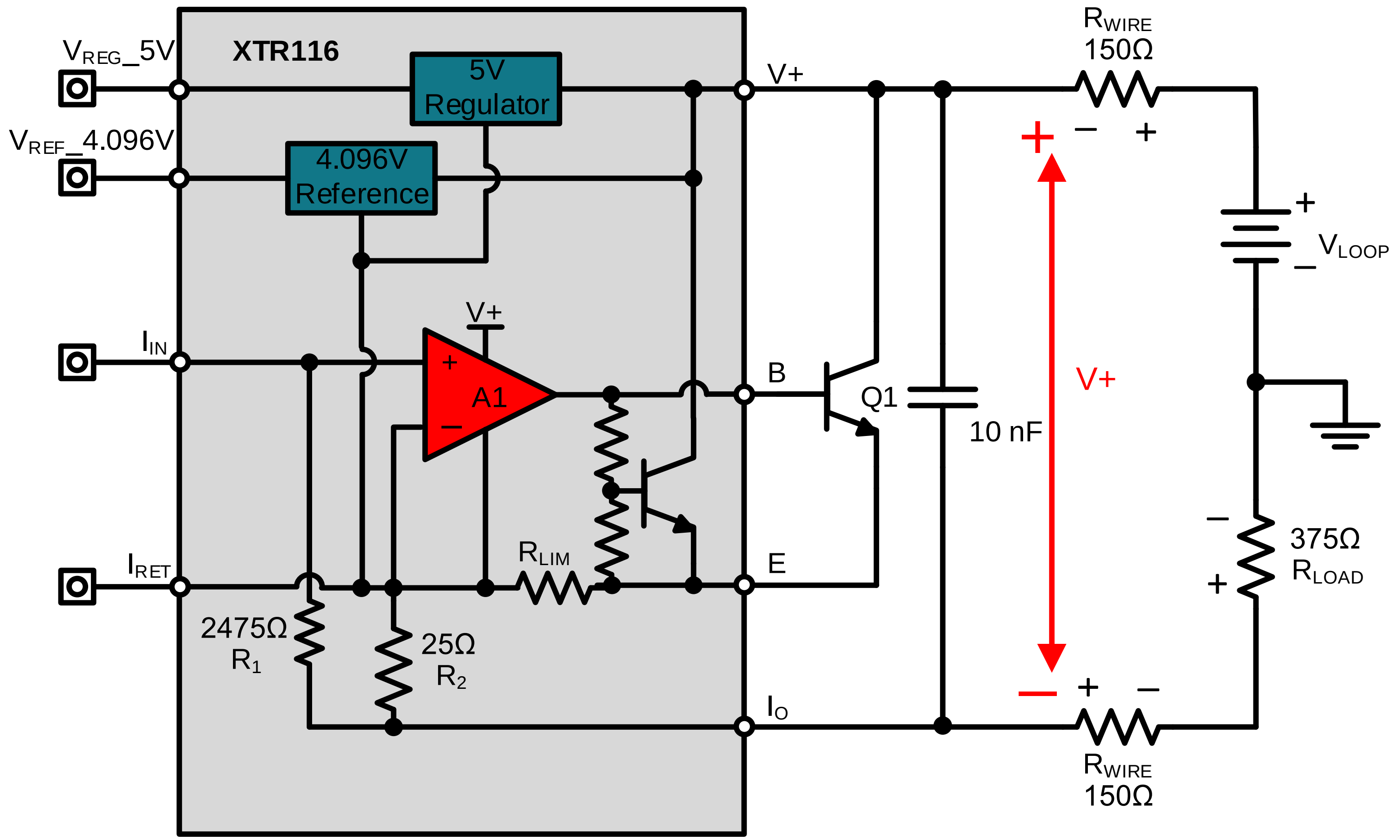


The input to this 2-wire transmitter is $I_{IN} = \left(\frac{V_{DAC}}{R_{IN}} + \frac{V_{REG}}{R_{OS}}\right)$. With a gain of 80 and a 5V regulator, the correct values for R_{IN} and R_{OS} are 25kΩ and 100kΩ.

Quiz: 2-wire 4-20mA Transmitters || Question

4. Due to the compliance voltage of the XTR116, what is the minimum V_{LOOP} that can be used if the wire resistance and load is as given in the figure and the expected transmitter output is 4-20mA.

a) 10V
b) 21V
c) 36V
d) 40V



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b) 21V

c) 36V

d) 40V

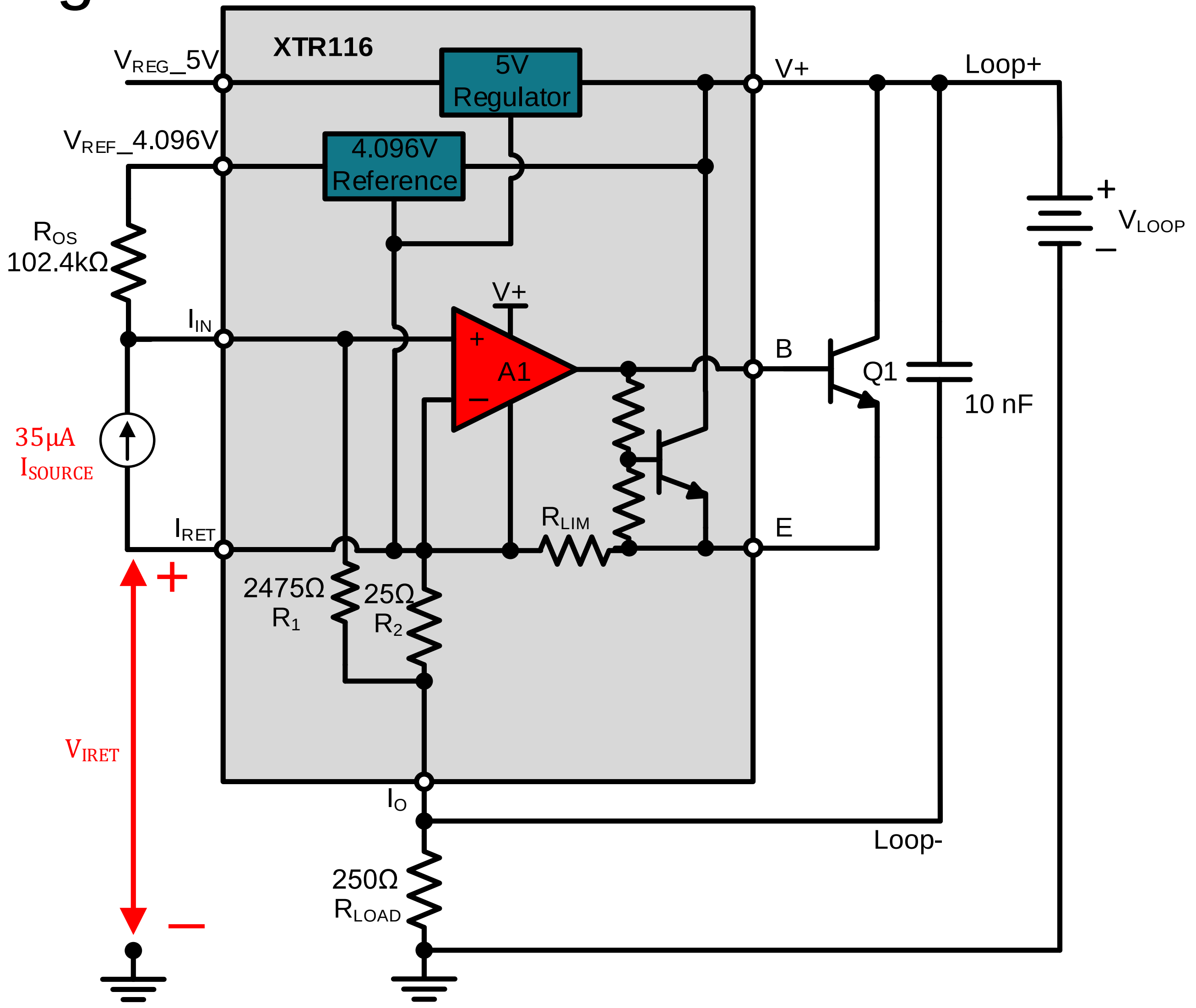
The XTR116 has a compliance voltage of 7.5V. This means that the VLOOP supply needs to be greater than the compliance voltage plus the max current and total resistance.

			MIN	TYP	MAX				
POWER SUPPLY	V+								
Specified				+24			*		V
Voltage Range			+7.5		+36	*		*	V
Quiescent Current				200	250		*	*	µA
Over Temperature, –40°C to +85°C				240	300		*	*	µA

Quiz: 2-wire 4-20mA Transmitters || Question

5. With a current input of 35uA and R_{OS}, and R_{LOAD} as shown in the figure, what is the voltage at I_{RET} referred to ground?

a) 1.65V
b) 2.06V
c) 3.79V
d) 4.54V



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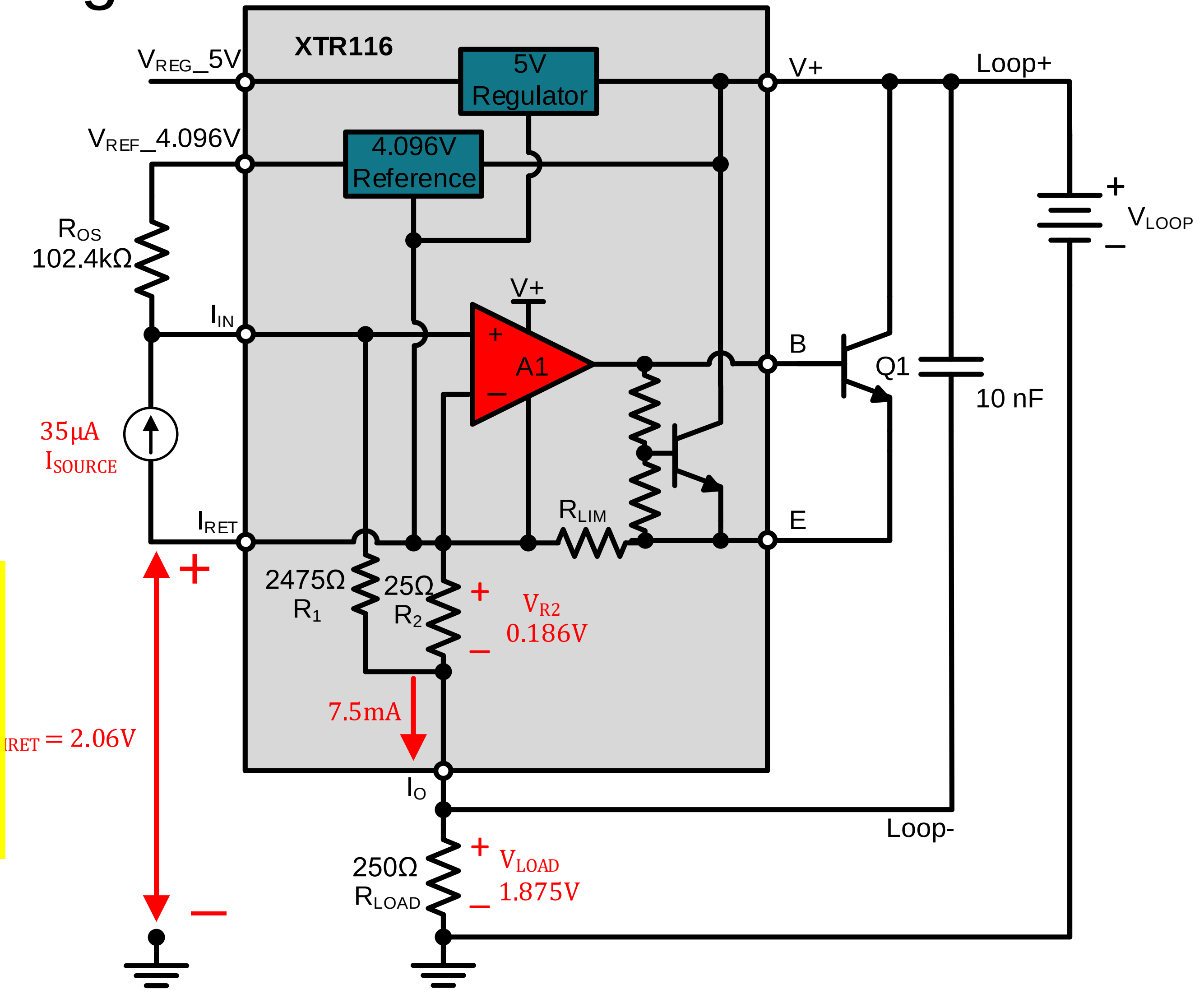

The voltage at I_{RET} is given by $V_{IRET} = V_{R2} + V_{LOAD}$. V_{R2} is calculated to be 0.186V and V_{LOAD} is calculated to be 1.875V, so V_{IRET} is 2.06V

Thanks for your time!

To find more Current Transmitter technical resources and search products, visit: https://www.ti.com/amplifier-circuit/special-function/4-20ma-signal-conditioners.html