Transistor sensor needs no compensation

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The thermometer circuit in **Fig 1** uses an inexpensive transistor to accurately measure temperature without compensation or calibration. Almost all transistor sensors use the base-emitter diode's voltage-shift with temperature as their sensing mechanism. Unfortunately, the *absolute* diode voltage is unpredictable, necessitating circuit calibration each time you fit a new transistor sensor.

The circuit in **Fig 1** overcomes this limitation. The circuit provides a 0-to-10V output corresponding to a 0-to-100°C input. Unadjusted error is $< \pm 1\%$.

The basis for the circuit is the predictable relationship between current and voltage in a transistor's V_{BE} junction. At room temperature, the V_{BE} junction diode shifts 59.16 mV per decade of current. The temperature dependence of this constant is 0.33%/°C, or 198 μV/°C. The ΔV_{BE}-vs-current relationship holds, regardless of the V_{BE} diode's *absolute* value.

An internal oscillator controls the state of the switches in IC_1, the LTC1043. The 0.01-μF capacitor at pin 16 sets the IC's oscillator frequency at about 500 Hz. Q_1 operates as a switched-value current source, alternating between about 10 and 100 μA as IC_1 commutates switch pins 12 and 14. The two currents' exact values are unimportant, so long as their *ratio* remains constant.

Because of this constant ratio, Q_1 requires no reference, although its emitter resistor's ratio must be precise. The alternating 10/100-μA stepped current drive

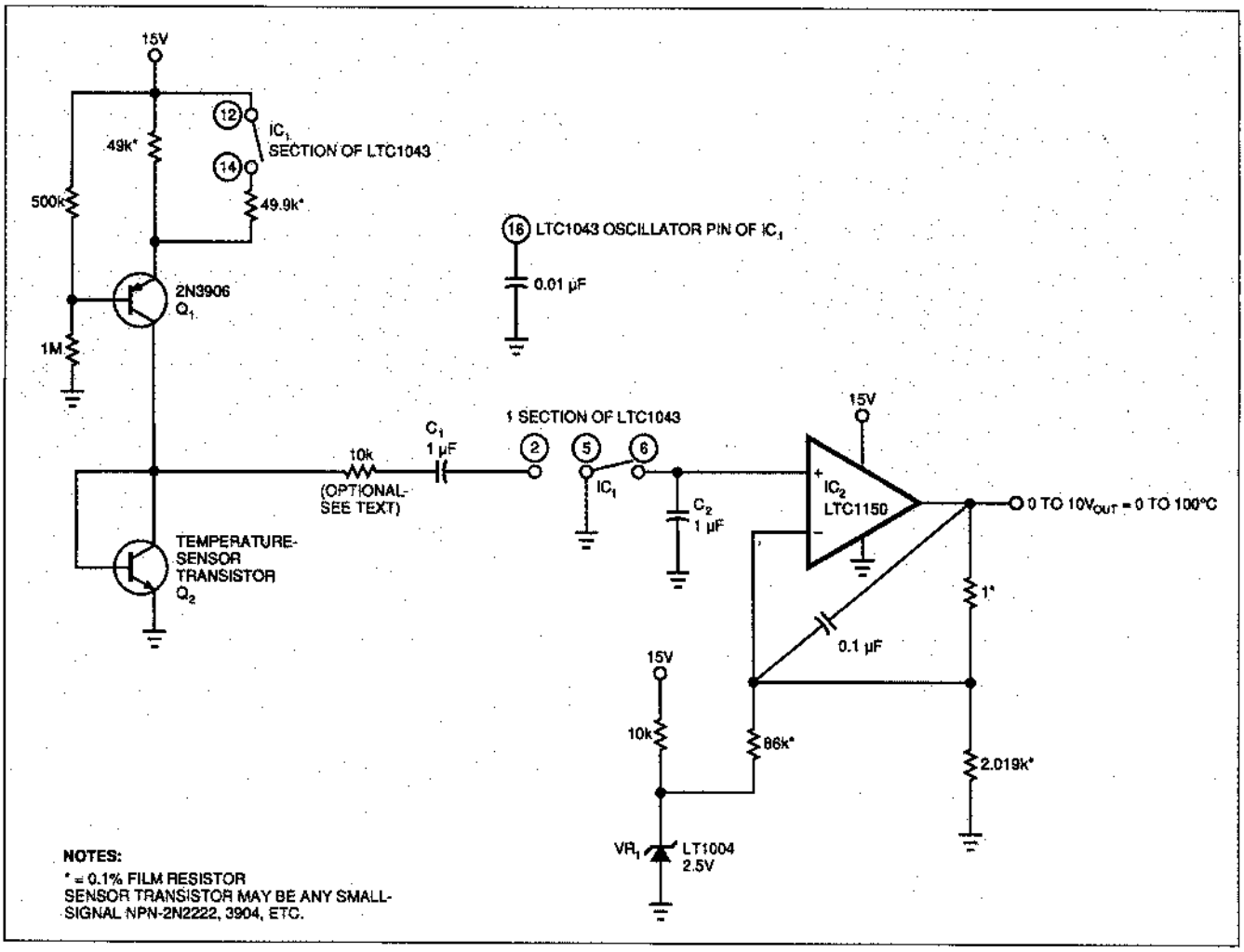


Fig 1—The transistor Q_2 senses temperature. *This circuit requires no compensation, even if you change transistors.*

to the sensor transistor, Q_2, causes the theoretical 59.16-mV excursion at 25°C to appear across the V_{BE} junction.

C_1 couples this signal to a switched demodulator that strips off Q_2's dc bias. Thus IC_1's pin 2 sees only the 59-mV waveform, which the demodulator action at pins 5 and 6 references to ground. Pin 5, connected to capacitor C_2, sits at pin 2's peak dc value. IC_2 amplifies this dc signal, with VR_1 providing offset so that 0°C equals 0V output. The optional 10-kΩ resistor protects against ESD (electrostatic discharge) events, which may occur if Q_2 is at the end of a cable.

Using the components in **Fig 1**, the circuit achieves ±1% error over a sensed 0-to-100°C range. Substituting randomly selected 2N3904s and 2N2222s for Q_2 showed less than 0.4°C spread over 25 devices from various manufacturers. **(EDN BBS /DI_SIG #945)**

EDN

Reference(s)

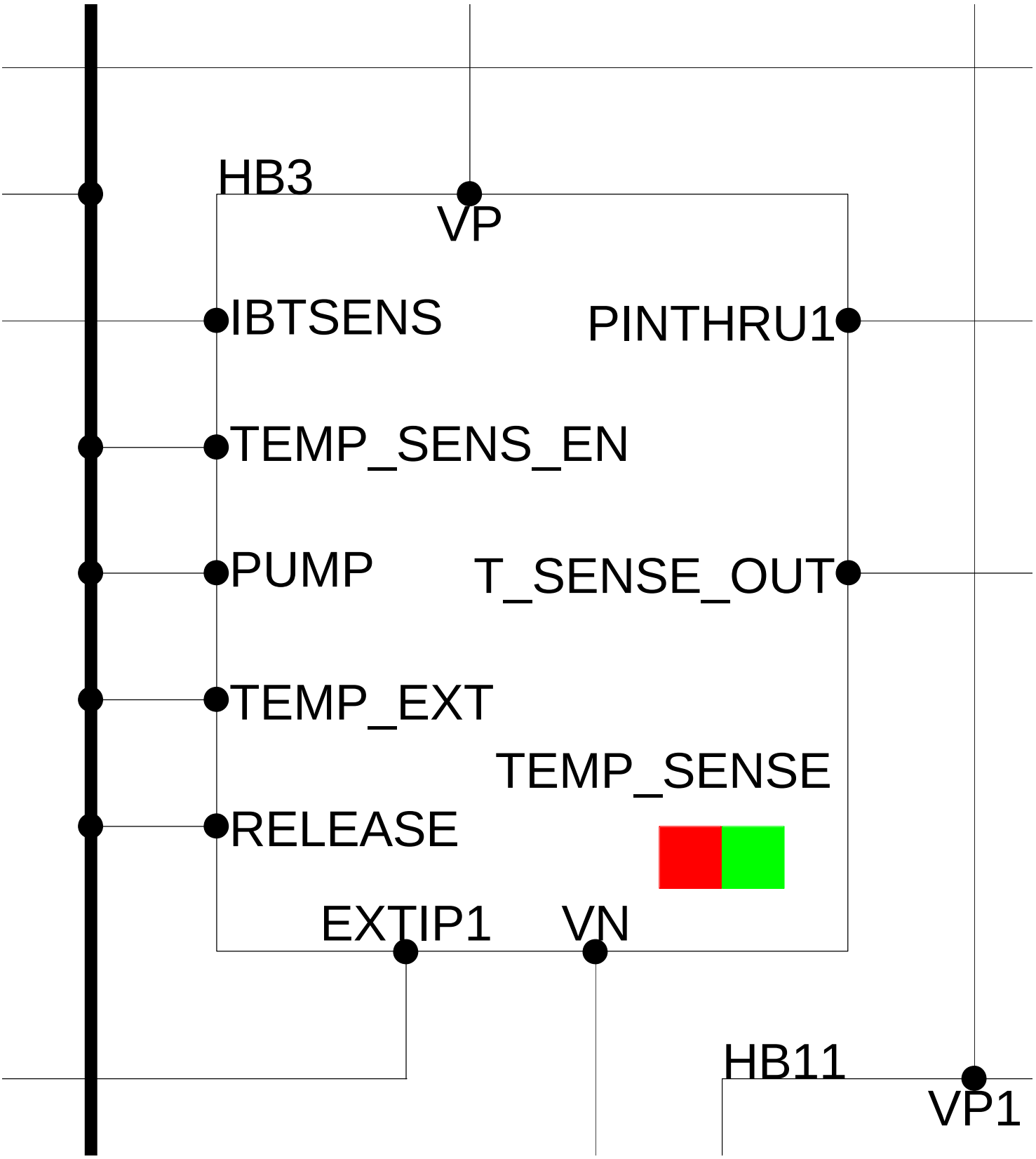
1. Verster, T C, "The Silicon Transistor as a Temperature Sensor," *International Symposium on Temperature*, 1971, Washington, DC.

2. Type 7013 Plug-In Operating and Service Manual, Tektronix Inc, 1971.

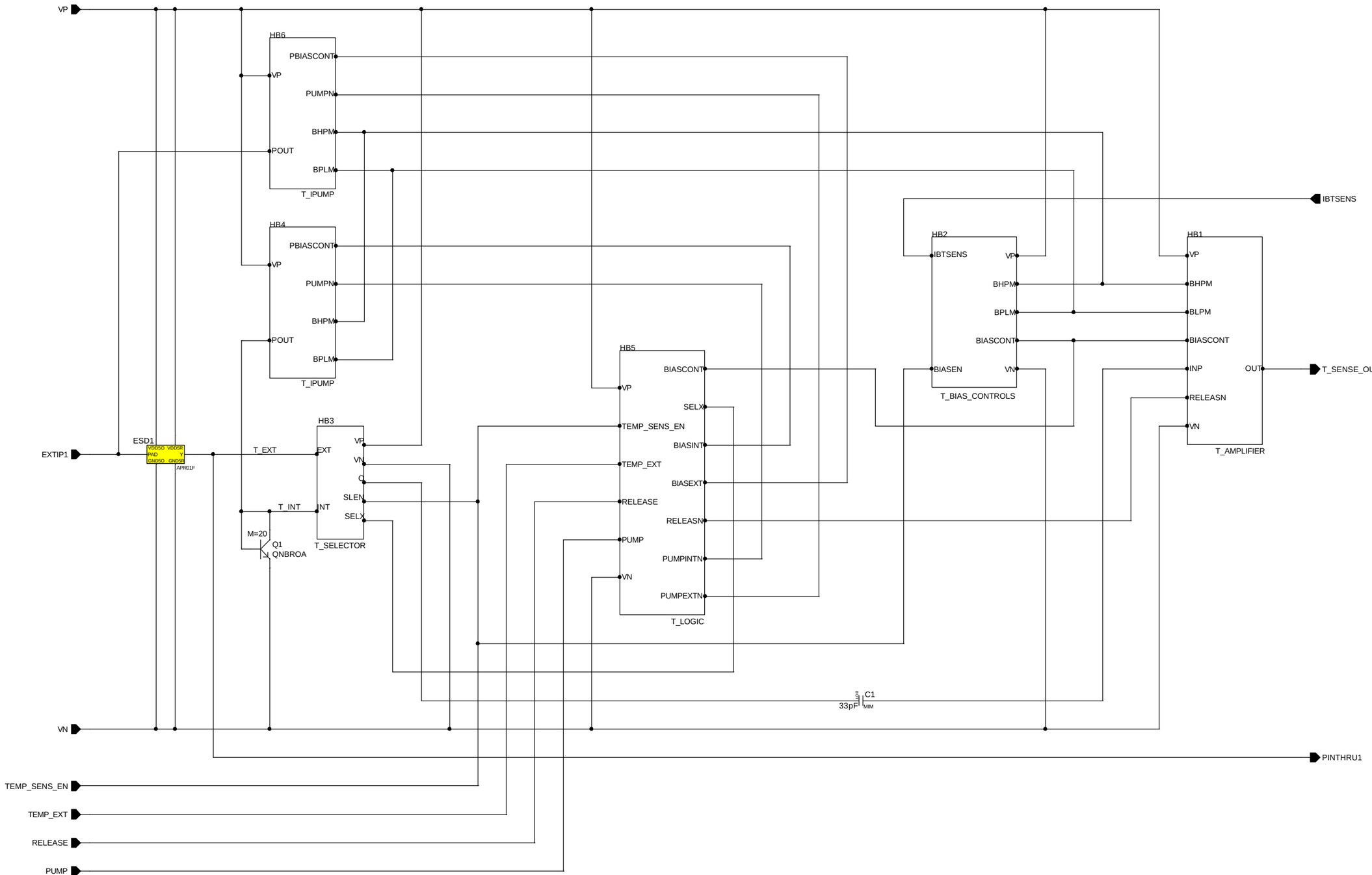
3. Sheingold, D H, "Non-Linear Circuits Handbook," Chapter 3-1, *Basic Considerations*, pp 165-166, Analog Devices Inc, 1974.

To Vote For This Design, Circle No. 747

THE FOLLOWING PAGES SHOW MY INTEGRATED CIRCUIT IMPLEMENTATION OF JIM WILLIAMS' IDEA...



THIS IS A HIERARCHICALLY NEGOTIABLE DRAWING: CLICK ON A BLOCK TO DESCEND, CLICK ON A "VIEW" BUTTON TO ASCEND.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VP
PUMPN
BHPM
POUT
BPLM
T_IPUMP
HB4
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VP
PUMPN
BHPM
POUT
BPLM
T_IPUMP
HB3
ESD1
VDDSO VDDSR
PAD Y
GNDSO GNDSR
APR01F
EXTIP1
T_EXT
EXT
VP
VN
CL
SLEN
T_INT
INT
SELX
M=20
Q1
QNBROA
T_SELECTOR
HB5
BIASCONT
VP
SELX
TEMP_SENS_EN
BIASINT
TEMP_EXT
BIASEXT
RELEASE
RELEASN
PUMP
PUMPINTN
VN
PUMPEXTN
T_LOGIC
HB2
IBTSENS
VP
BHPM
BPLM
BIASCONT
BIASEN
VN
T_BIAS_CONTROLS
HB1
VP
BHPM
BLPM
BIASCONT
INP
OUT
RELEASN
VN
T_AMPLIFIER
IBTSENS
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VN
PINTHRU1
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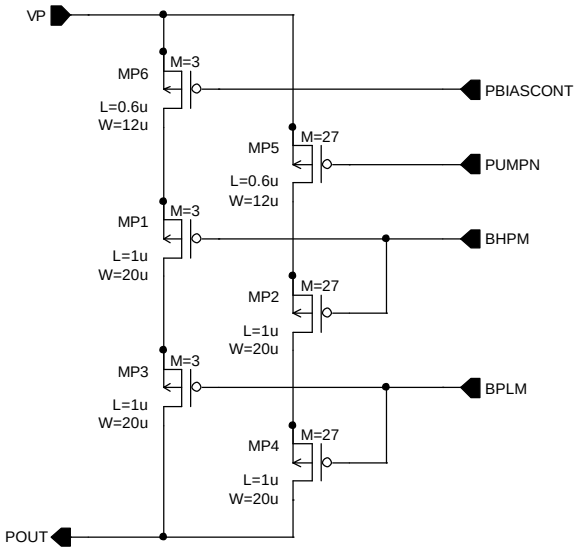
TEMP_EXT
RELEASE
PUMP
BLOCK VIEW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M=3
L=1u
W=20u
BHPM
MP2
M=27
L=1u
W=20u
MP3
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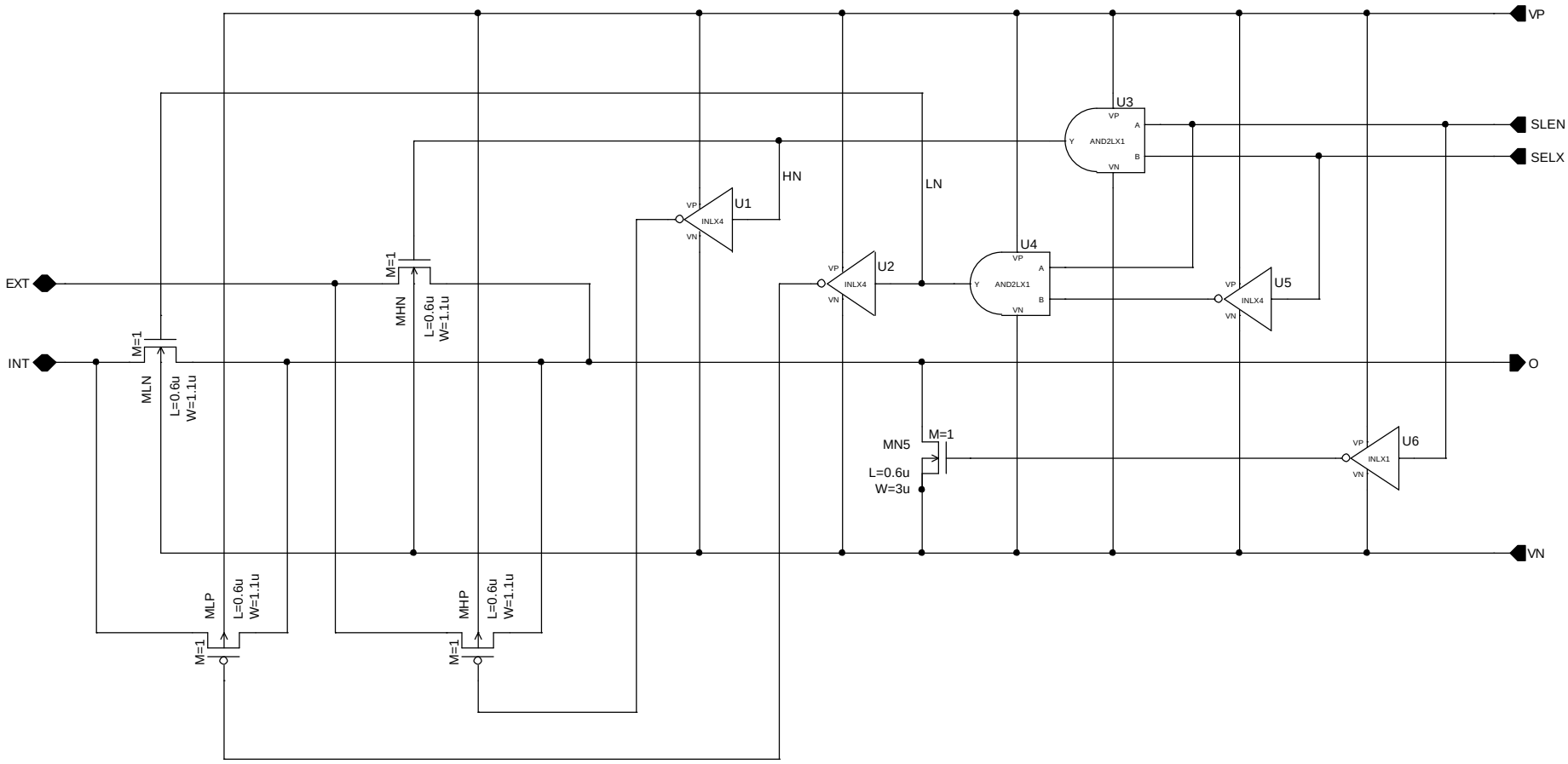
L=1u
W=20u
BPLM
MP4
M=27
L=1u
W=20u
POUT

TOP VIEW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HN
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U2
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U4
U5
U6
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AND2LX1
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MLP
MHP
MN5
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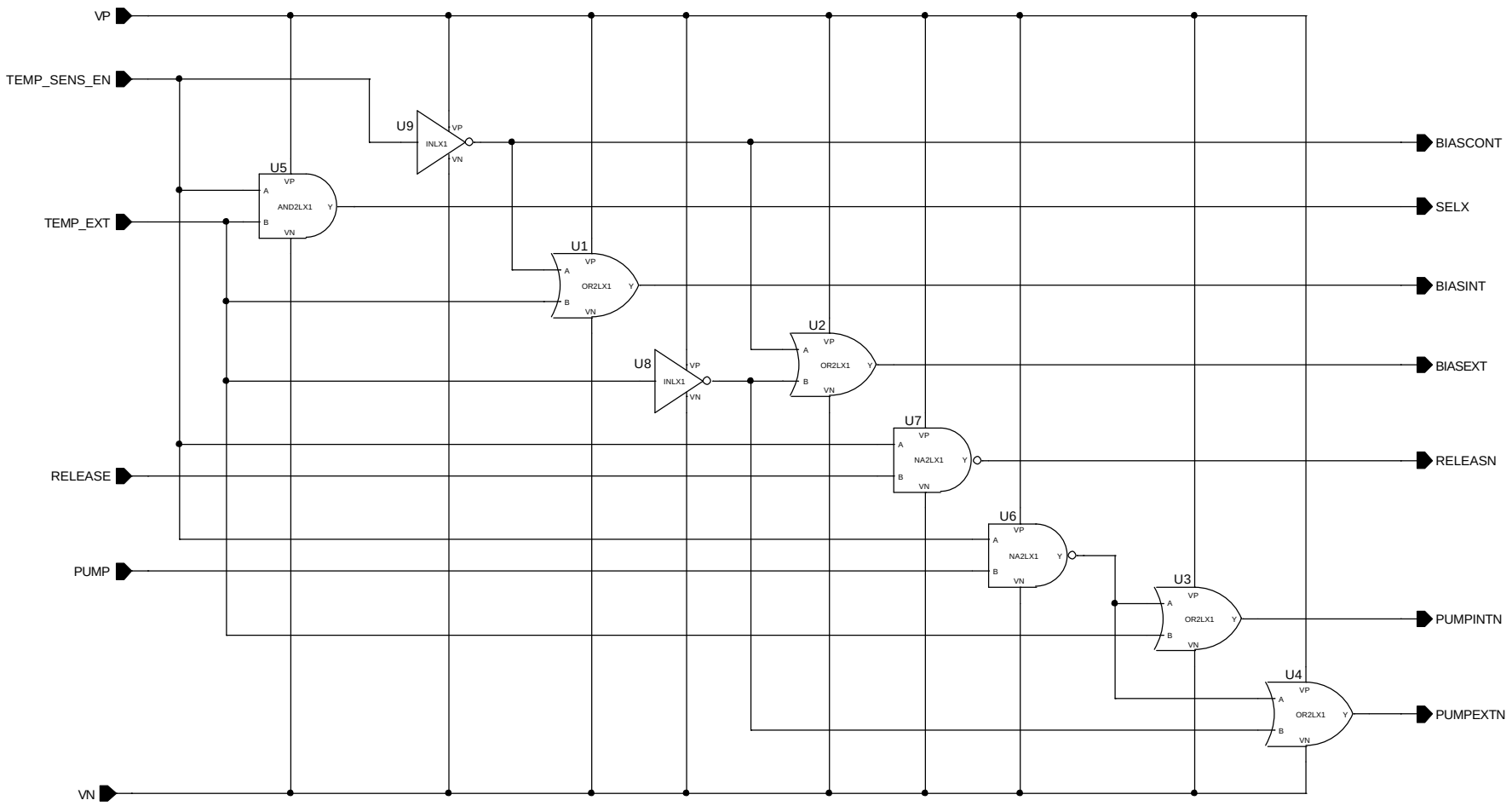
TOP VIEW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VP
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U5
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A
B
Y
U1
OR2LX1
U8
U2
U7
NA2LX1
U6
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U4
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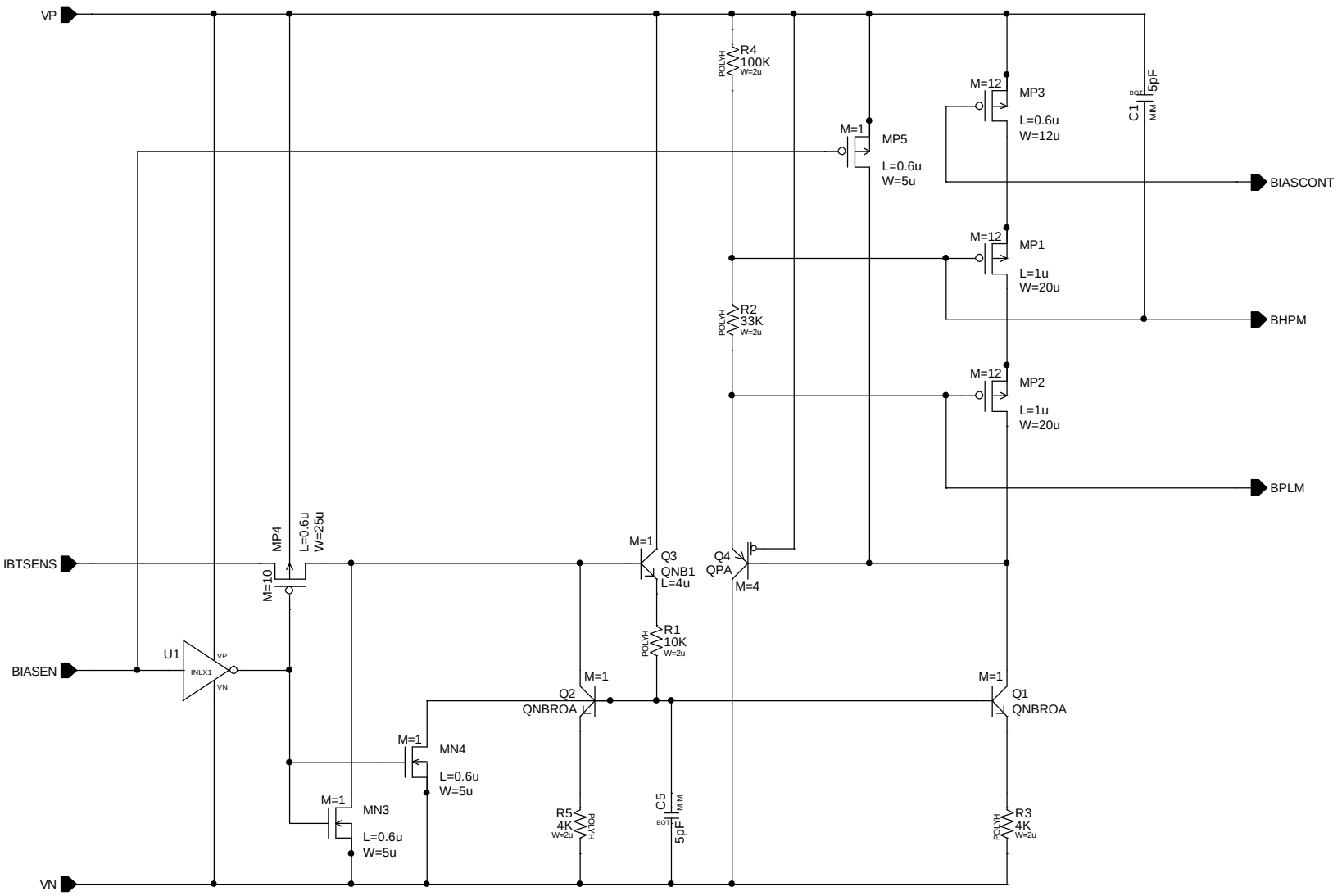
RELEASN
PUMPINTN
PUMPEXTN

TOP VIEW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W=5u
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MP1
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R2
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BHPM
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MP2
L=1u
W=20u
BPLM
IBTSENS
MP4
L=0.6u
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M=10
M=1
Q3
QNB1
L=4u
Q4
QPA
b
M=4
R1
10K
W=2u
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INLX1
VP
VN
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Q2
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Q1
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MN3
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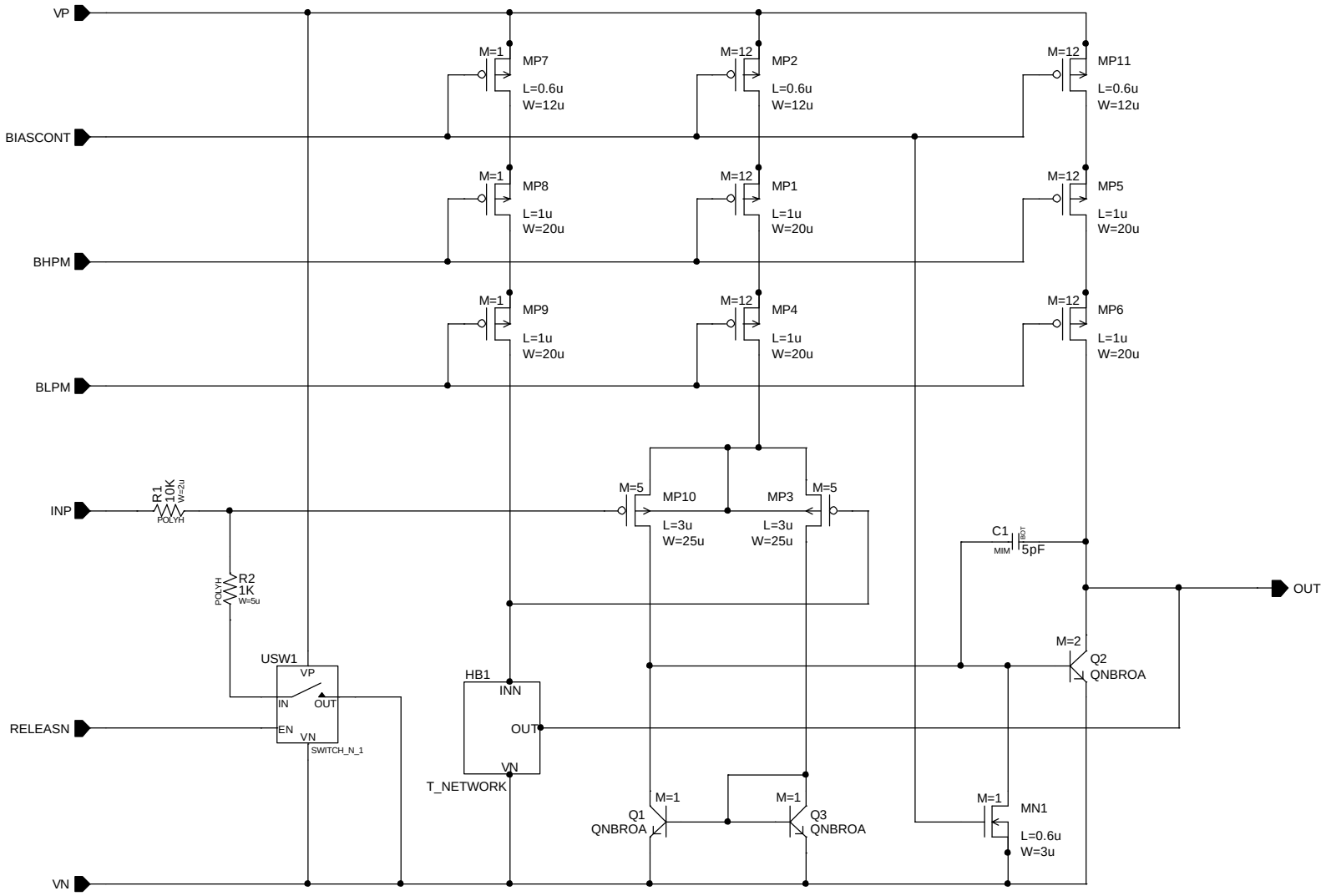
4K
W=2u
VN

TOP VIEW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R2
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MP3
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MIM
BOT
5pF
OUT
USW1
VP
IN
OUT
EN
VN
SWITCH_N_1
HB1
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OUT
VN
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Q1
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Q3
QNBROA
MN1
L=0.6u
W=3u

TOP VIEW