IEEE 802.3ap

Transmitter Tap Range Selection

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TX Tap Selection

- Previous transmitter tap analysis used the assumption that the transmitter would always be transmitting at maximum power.
- Normalizing the tap magnitudes to 1 is a convenient mathematical formula but from a system perspective, there appears to be a better working model.
- First lets look at the details of the ‘always at max power’ approach.
- Given the nominal 100-ohm double-terminated system, the voltages can be converted into tail currents on a multi-tap TX.
- All values will be generated using the nominal 1Vpp. Corner cases will need to be evaluated.

Always at Max Power

Values were clipped because Vss approached 0

Main-cursor Tap current [mA]

Pre-cursor Tap current [mA]

-3.5	16.5	16.0	15.5	15.0	14.5	14.0	13.5	13.0	12.5	12.0	11.5	11.0				
-3.0	17.0	16.5	16.0	15.5	15.0	14.5	14.0	13.5	13.0	12.5	12.0	11.5	11.0			
-2.5	17.5	17.0	16.5	16.0	15.5	15.0	14.5	14.0	13.5	13.0	12.5	12.0	11.5	11.0		
-2.0	18.0	17.5	17.0	16.5	16.0	15.5	15.0	14.5	14.0	13.5	13.0	12.5	12.0	11.5	11.0	
-1.5	18.5	18.0	17.5	17.0	16.5	16.0	15.5	15.0	14.5	14.0	13.5	13.0	12.5	12.0	11.5	11.0
-1.0	19.0	18.5	18.0	17.5	17.0	16.5	16.0	15.5	15.0	14.5	14.0	13.5	13.0	12.5	12.0	11.5
-0.5	19.5	19.0	18.5	18.0	17.5	17.0	16.5	16.0	15.5	15.0	14.5	14.0	13.5	13.0	12.5	12.0
0.0	20.0	19.5	19.0	18.5	18.0	17.5	17.0	16.5	16.0	15.5	15.0	14.5	14.0	13.5	13.0	12.5
	0.0	-0.5	-1.0	-1.5	-2.0	-2.5	-3.0	-3.5	-4.0	-4.5	-5.0	-5.5	-6.0	-6.5	-7.0	-7.5

0mV
50mV
100mV
Vss

Post-cursor Tap current [mA]

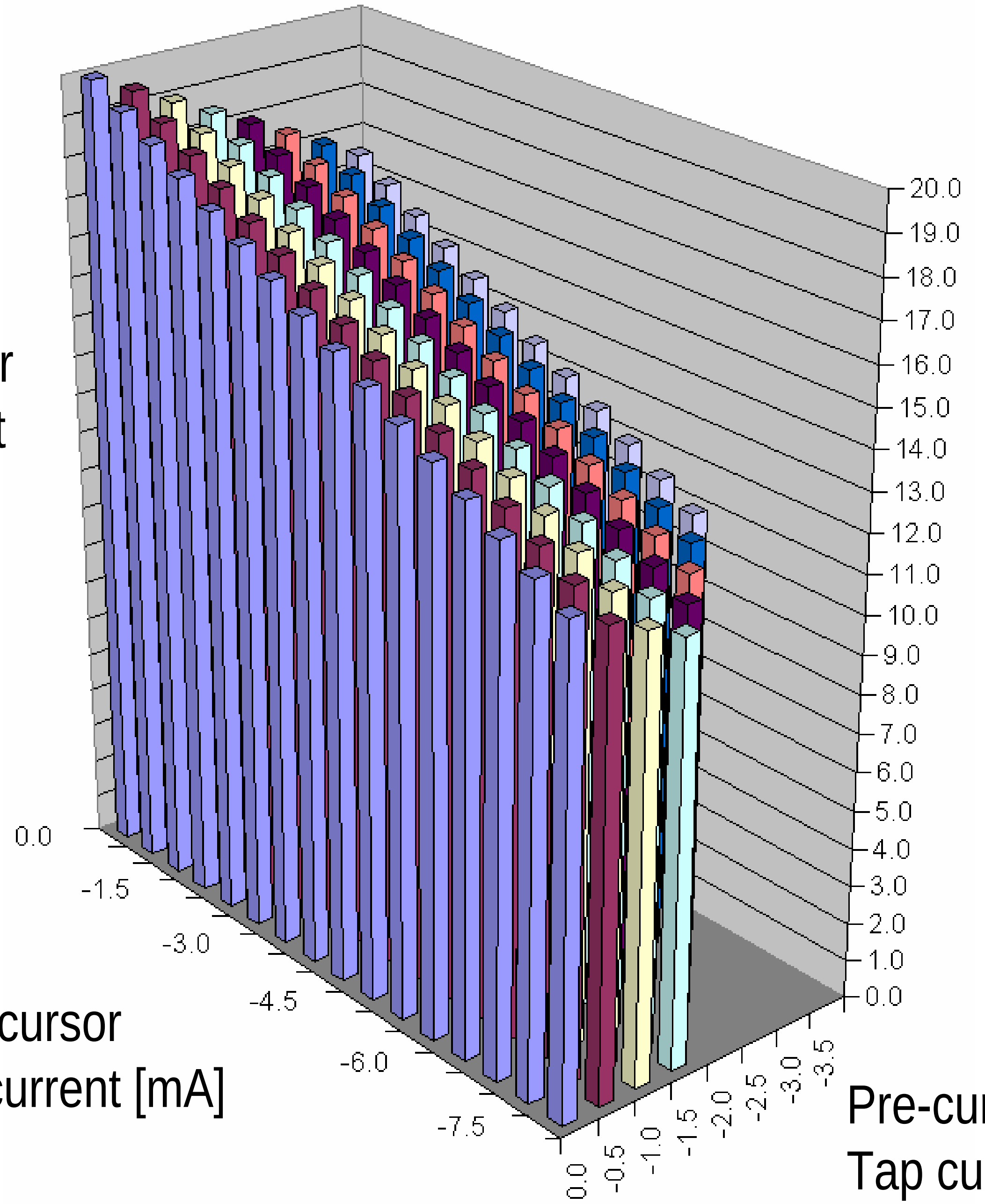
Vpeak = 1Vpp always

Vss = steady-state voltage = sum of taps
Vpeak = max swing = sum of magnitudes of taps

The main-cursor tap is forced to move with the pre and post cursor taps such that the sum of the magnitudes of the taps equals 1Vppdi

Always at Max Power

Main-cursor Tap current [mA]



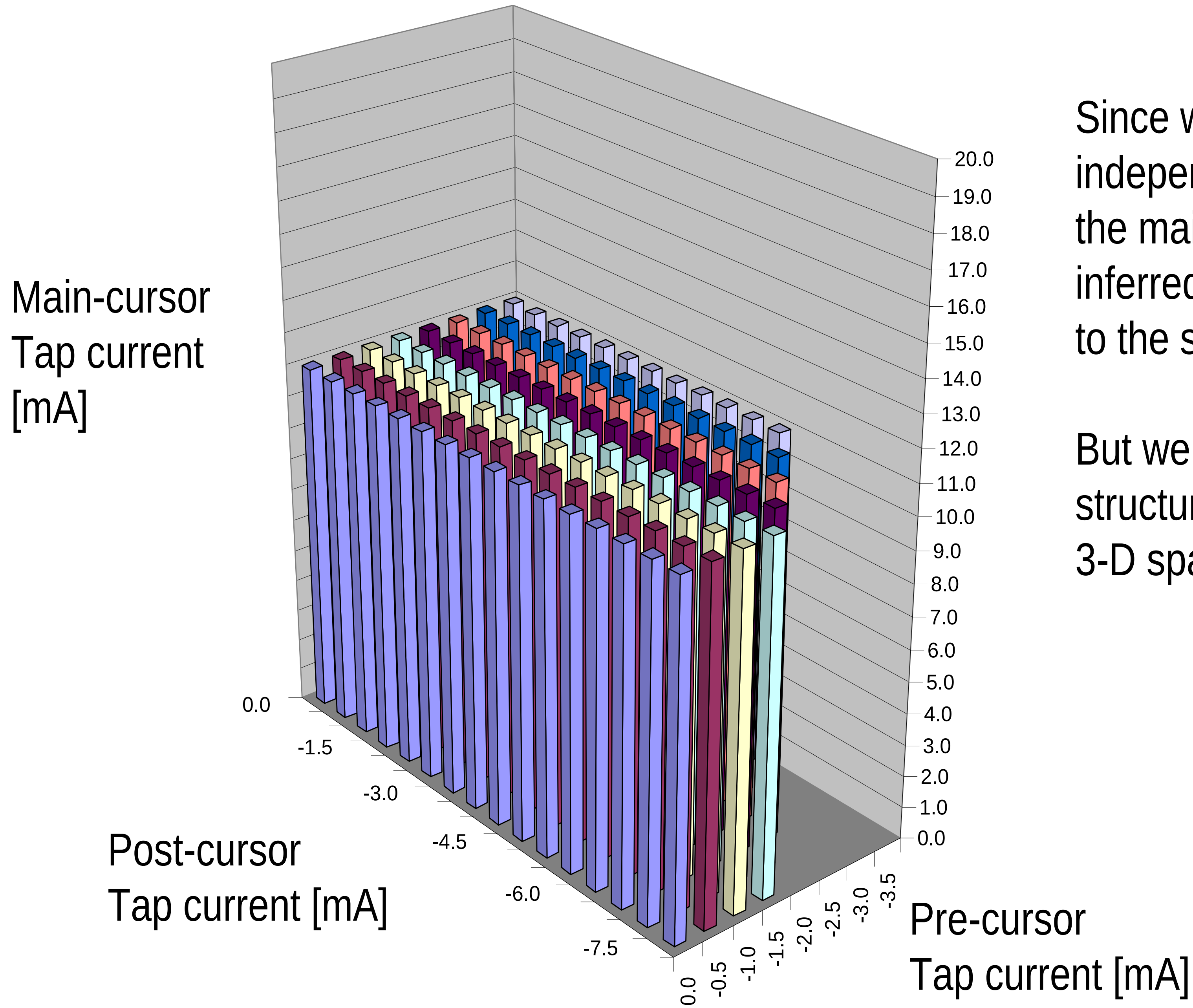
Post-cursor Tap current [mA]

Pre-cursor Tap current [mA]

Graphical representation of what is happing to the main-cursor tap as the other taps are changing.

The main tap is increasing as the other taps are decreasing

Always at Max Power

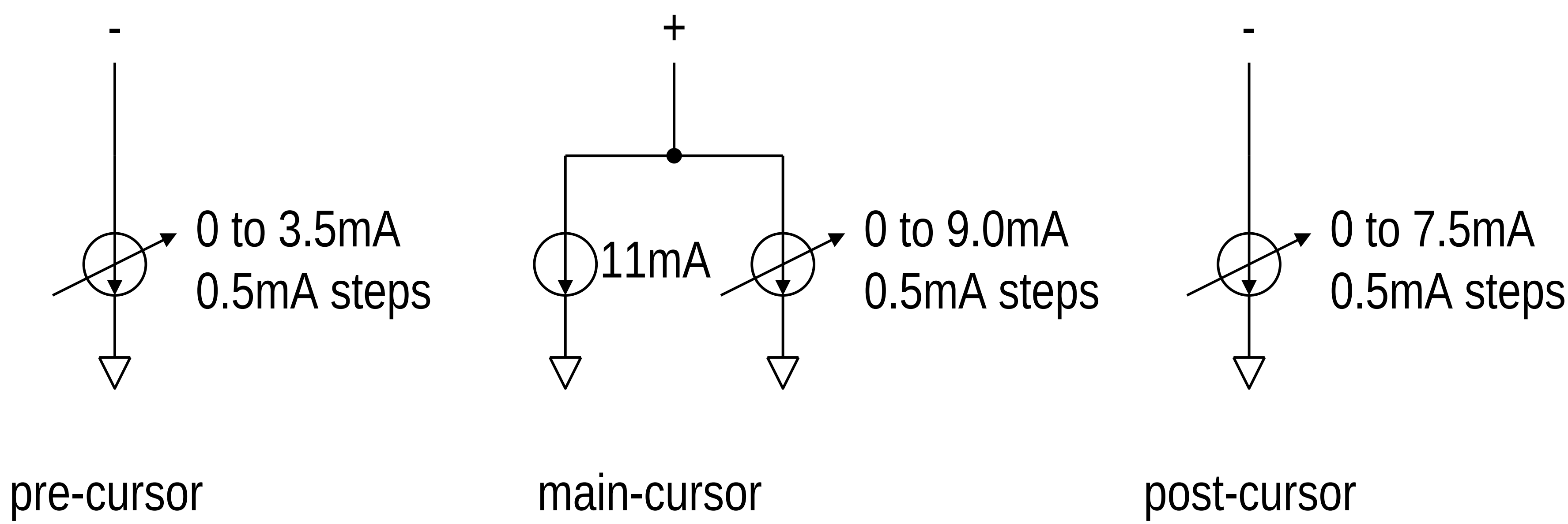


Since we retained independent control of the main-tap, it can be inferred we have down to the settings shown.

But we need the spec structured to ensure the 3-D space is available

Always at Max Power

Representative tail-current based implementation



Circuit needs to be designed to support a total of 31.0mA

Alternative – Keep Constant Vss

- From a system perspective, a more natural operational model is one where the Vss is held generally constant.
- This offers several system advantages:
  - Reduced crosstalk
  - Reduced transmit power (heat)
  - Reduced transmitter area
  - Reduced transmit reflections (return loss)
  - Reduced receiver linearity (power/heat)
- What does a constant Vss approach look like?

Constant Vss

Values are clipped
because Vpeak =1Vppdi

Main-cursor Tap current [mA]

Pre-cursor Tap current [mA]

-3.5	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0				
-3.0	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0			
-2.5	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0		
-2.0	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	
-1.5	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0
-1.0	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5
-0.5	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
0.0	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5
	0.0	-0.5	-1.0	-1.5	-2.0	-2.5	-3.0	-3.5	-4.0	-4.5	-5.0	-5.5	-6.0	-6.5	-7.0	-7.5

1.1V
1.05V
1V
Vpeak

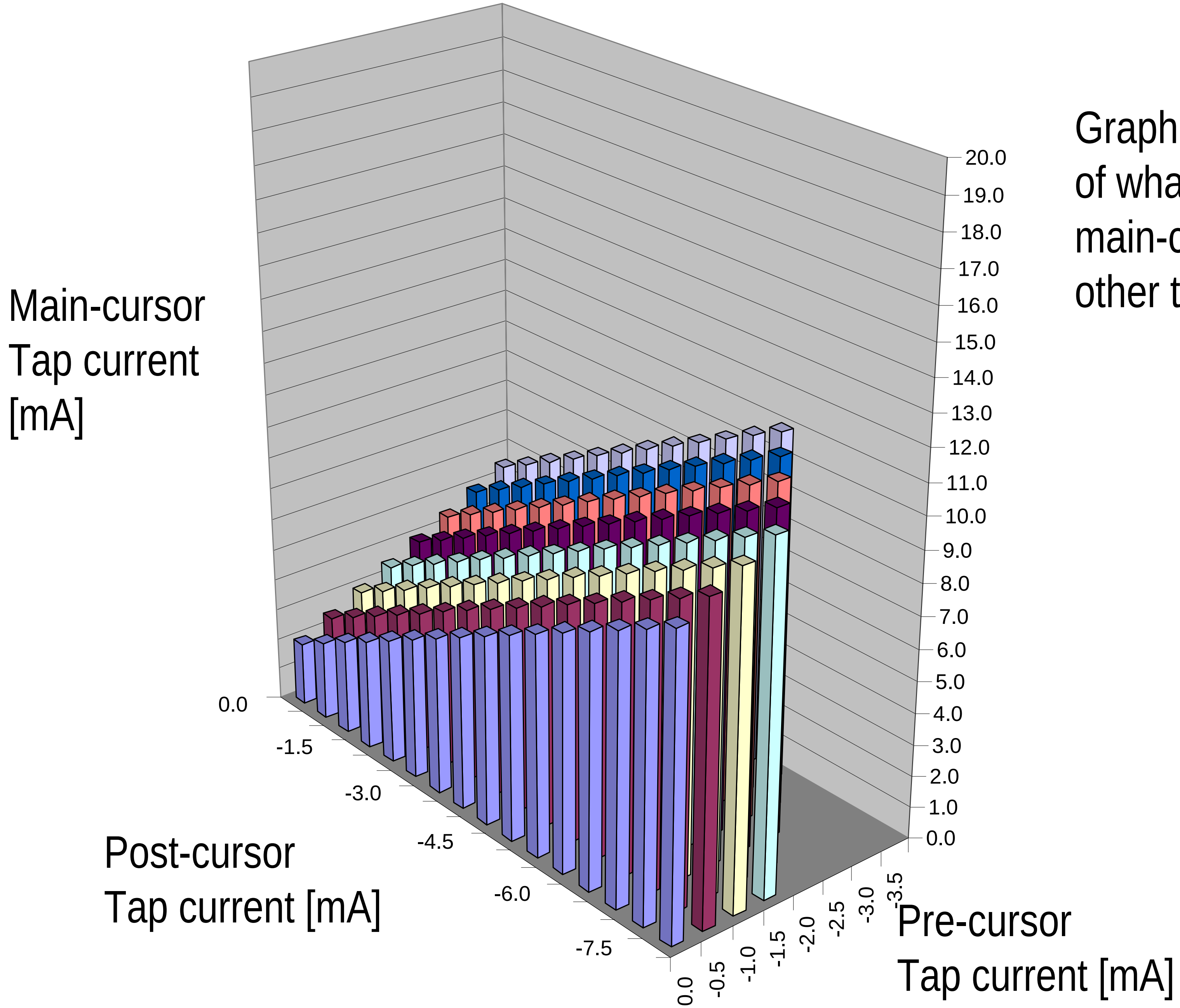
Post-cursor Tap current [mA]

Vss = 100mVpp always

Vss = steady-state voltage = sum of taps
Vpeak = max swing = sum of magnitudes of taps

With Constant Vss, the main-cursor tap is forced to move with the pre and post cursor taps such that the sum of the taps equals 100mVppdi.

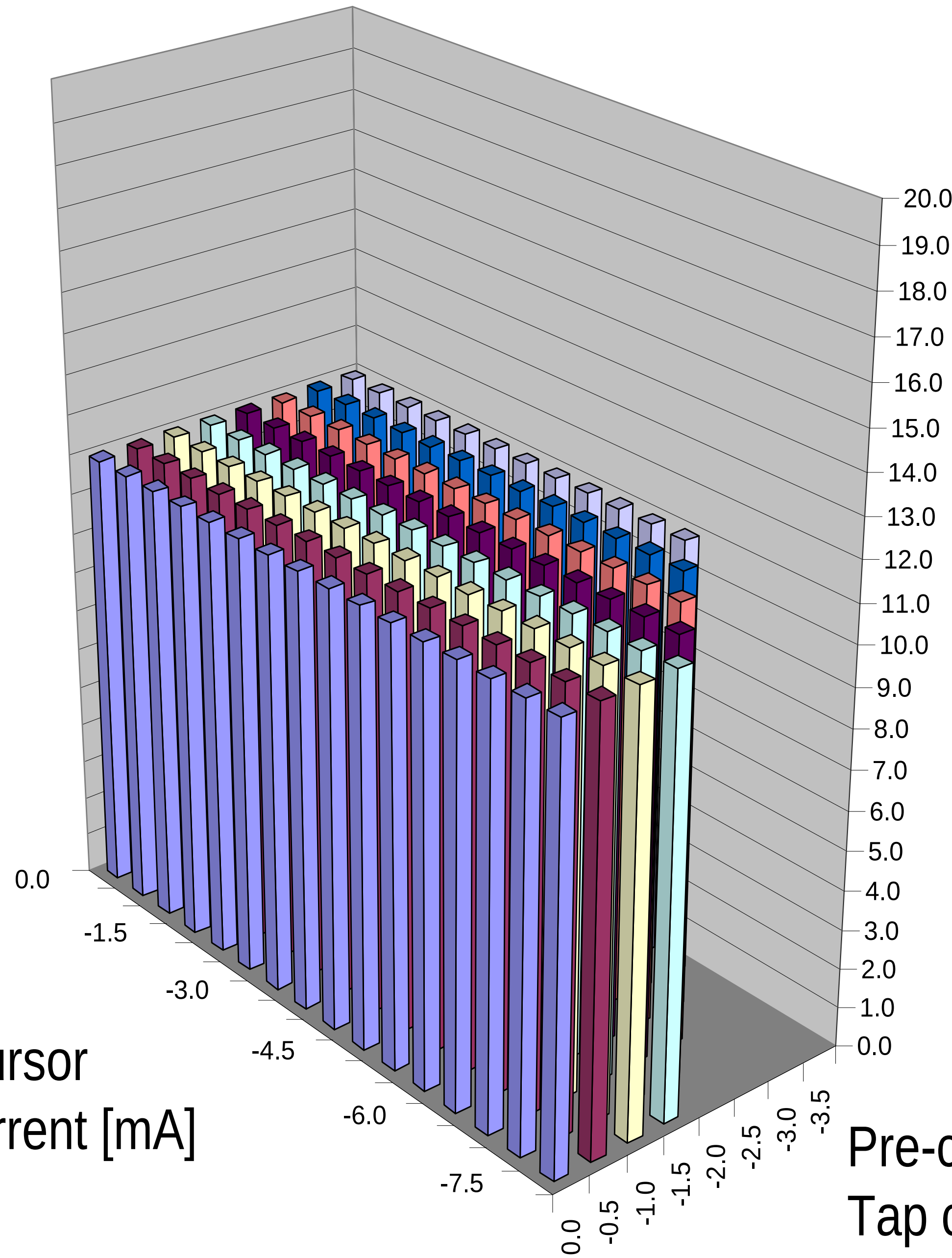
Constant Vss



Graphical representation of what is happing to the main-cursor tap as the other taps are changing

Constant Vss

Main-cursor
Tap current
[mA]



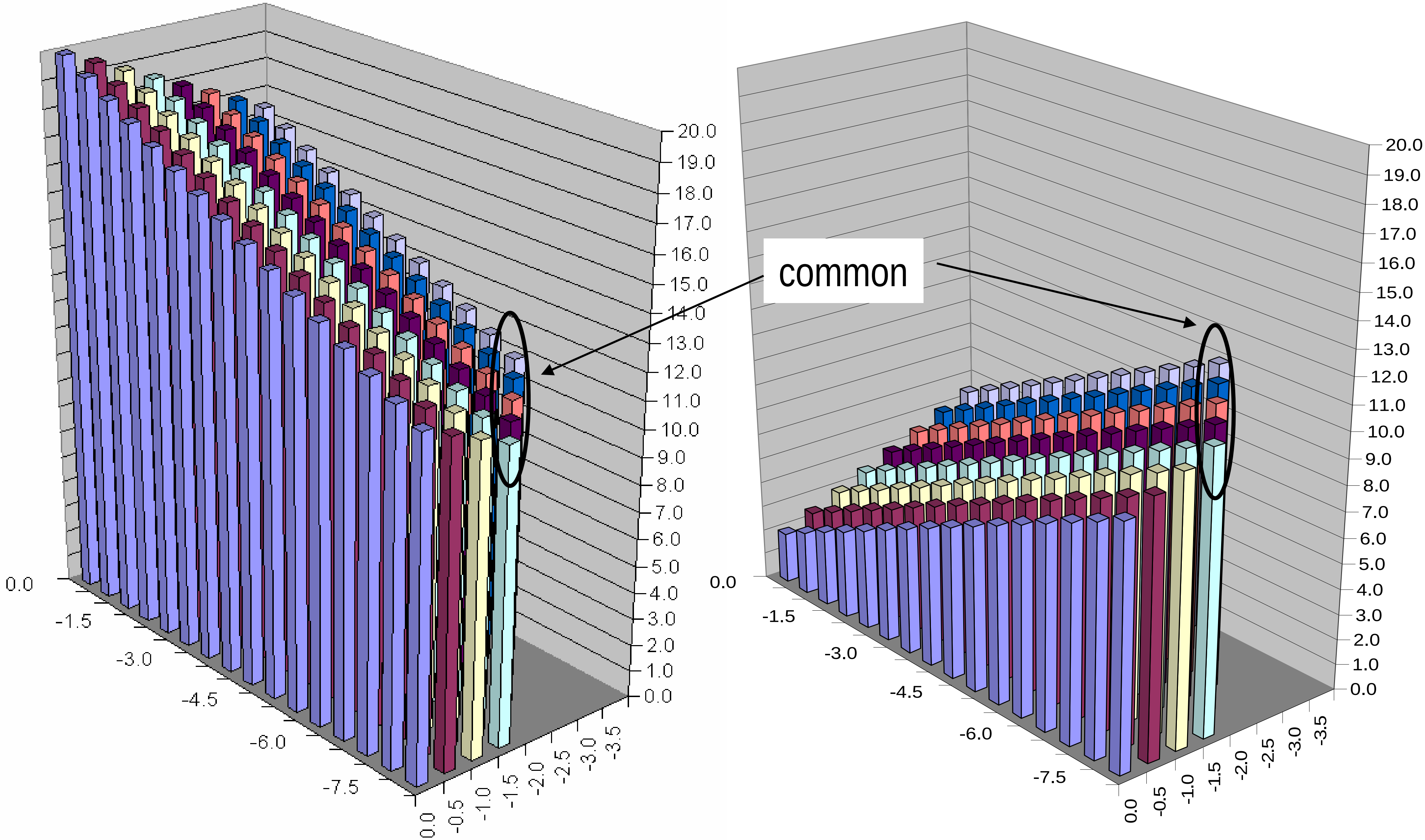
Post-cursor
Tap current [mA]

Pre-cursor
Tap current [mA]

Since we retained independent control of the main-tap, it can be Inferred we have up to the settings shown.

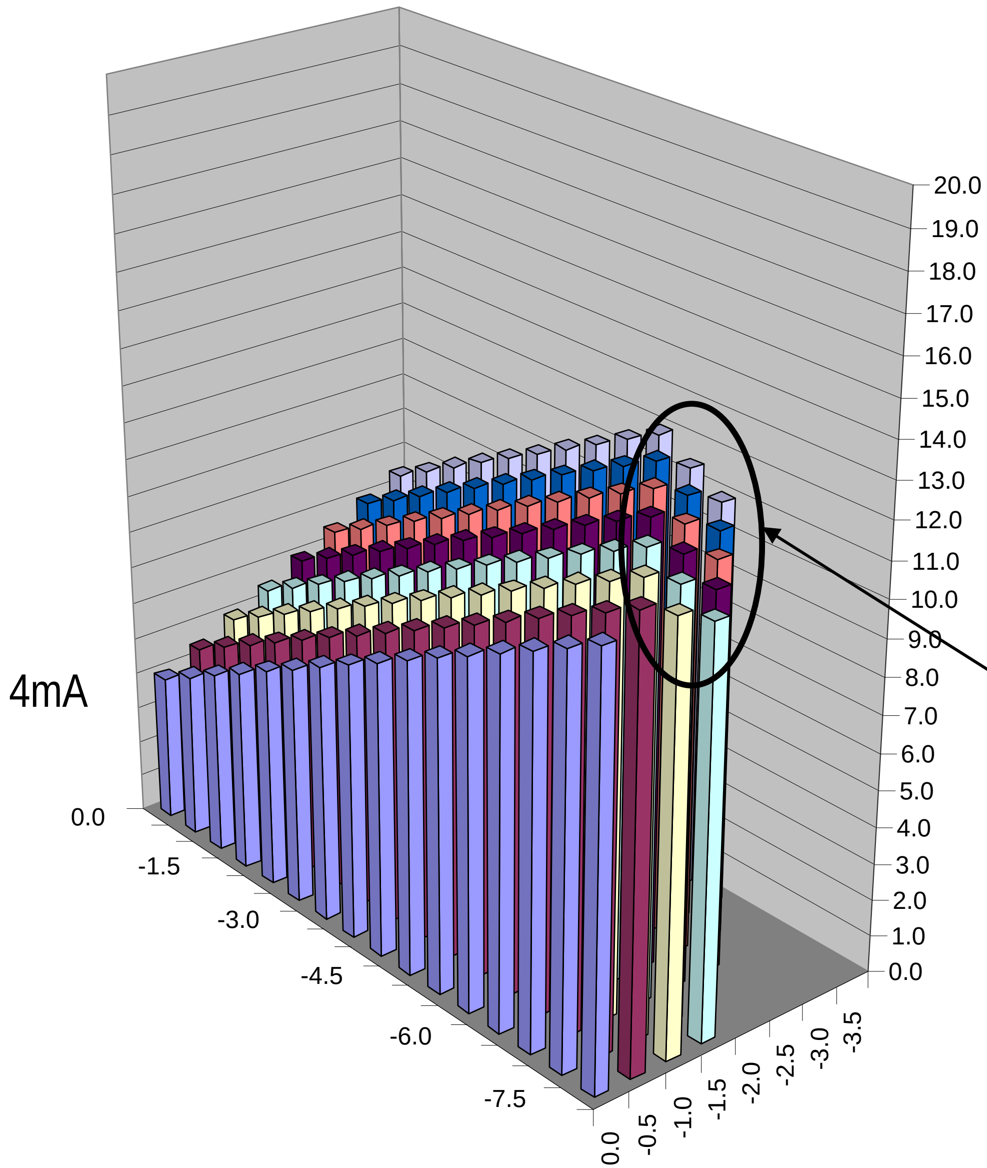
Can still transmit a non-equalized signal with 550mVppdi

Always at Max Power vs. Constant Vss



The solutions are perpendicular (orthogonal) slices through the same cube.

Constant Vss with 200mVpp Vss

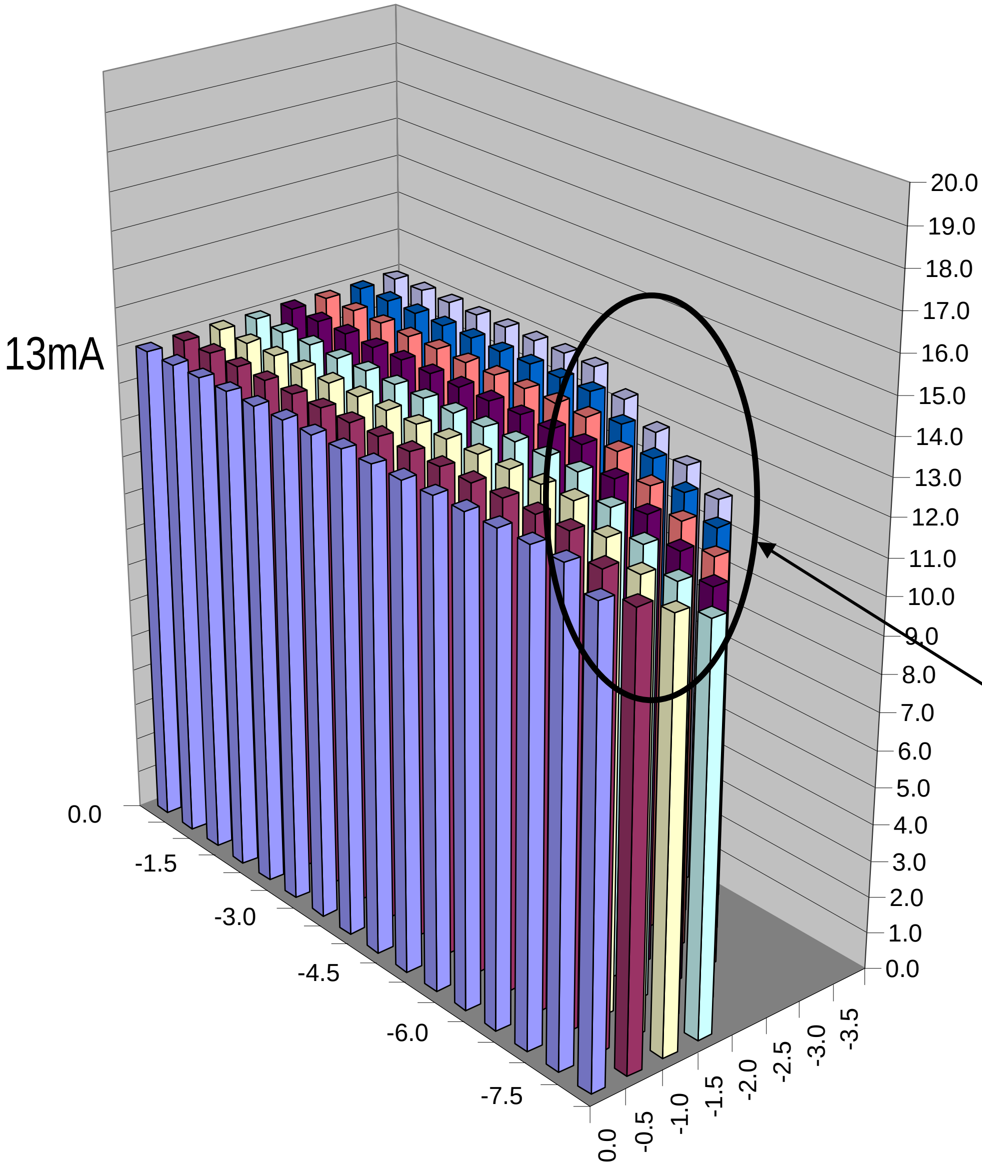


In order to provide a VSS target of 200mVpp for any setting (until Vpeak = 1V), we would increase the maximum of the main tap from 11mA to 13mA.

This would allow up to 650mVpp when transmitting with no equalization.

We picked up 2 diagonal rows that were contained in the original max power option.

Constant Vss with 200mVpp Vss

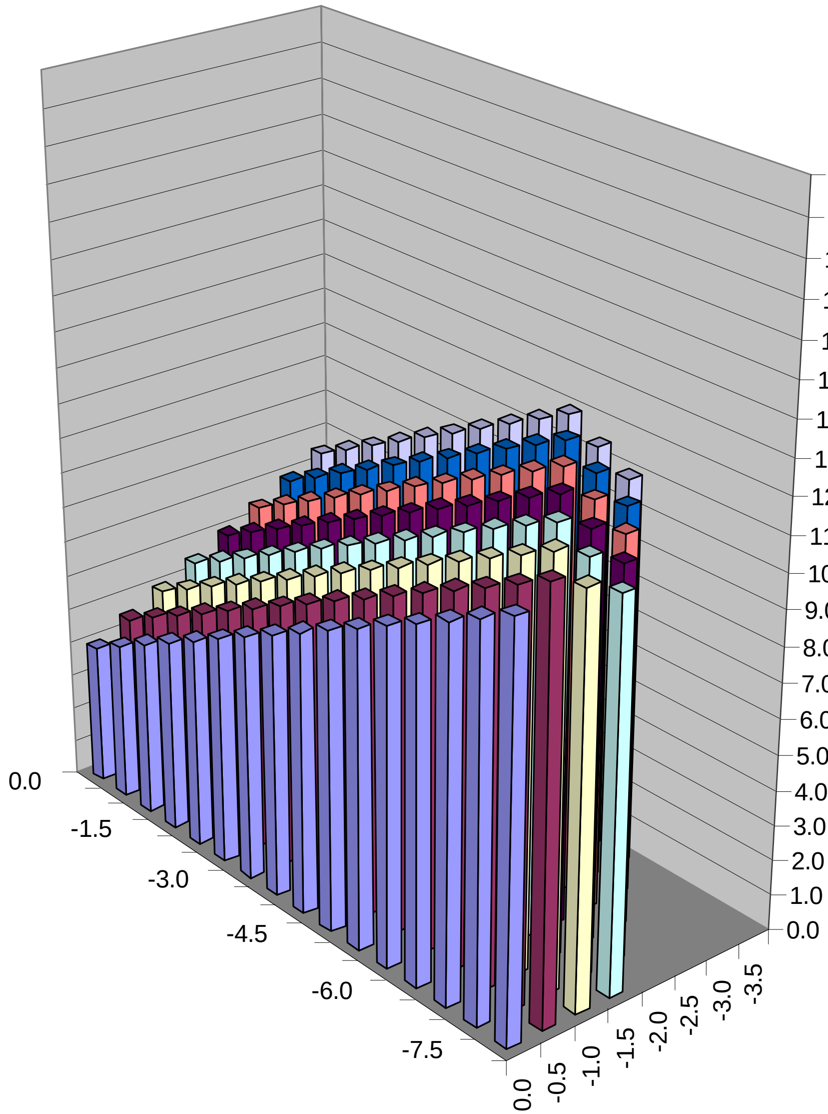


Choices with main tap at max possible

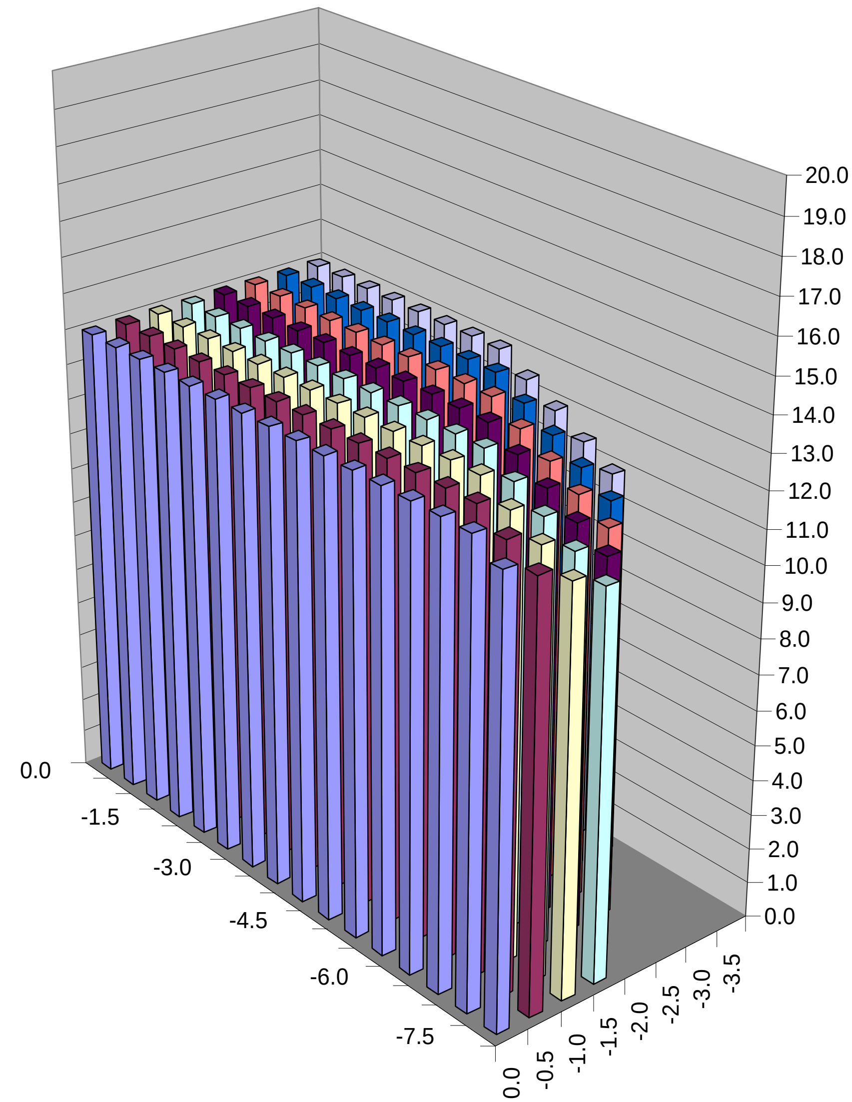
We picked up 4 diagonal rows that were contained in the original max power option.

Constant Vss with 200mVpp Vss

Choices with Vss = 200mV until Vpeak =1Vpp

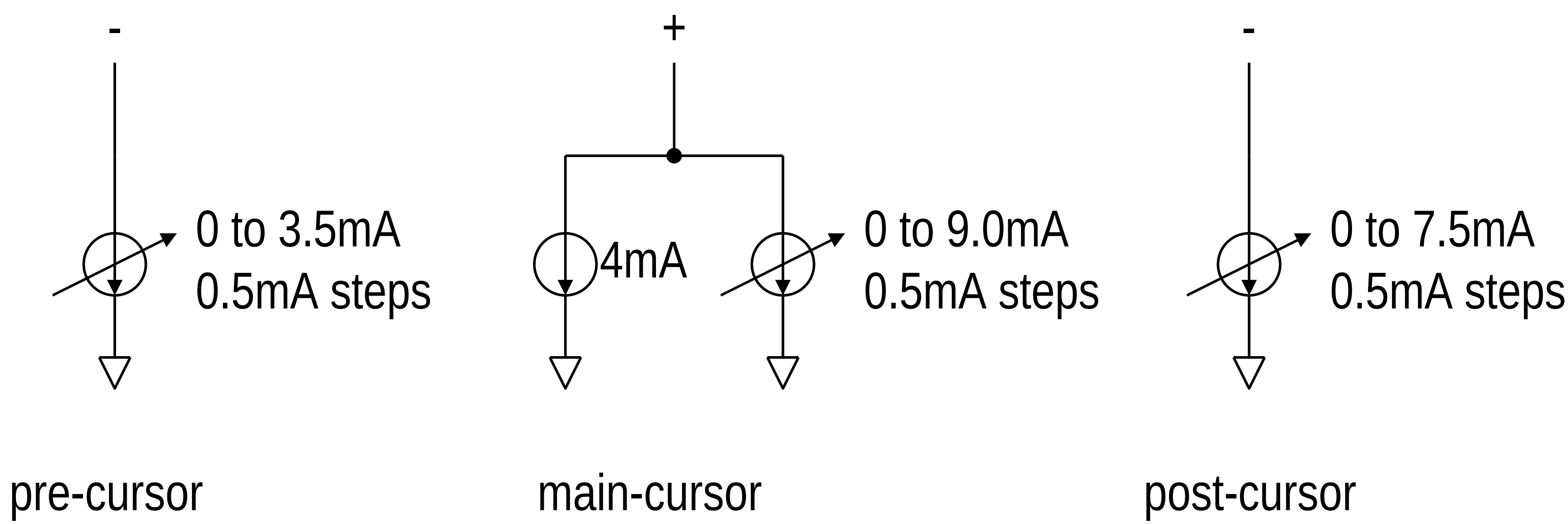


Choices with main tap at max possible



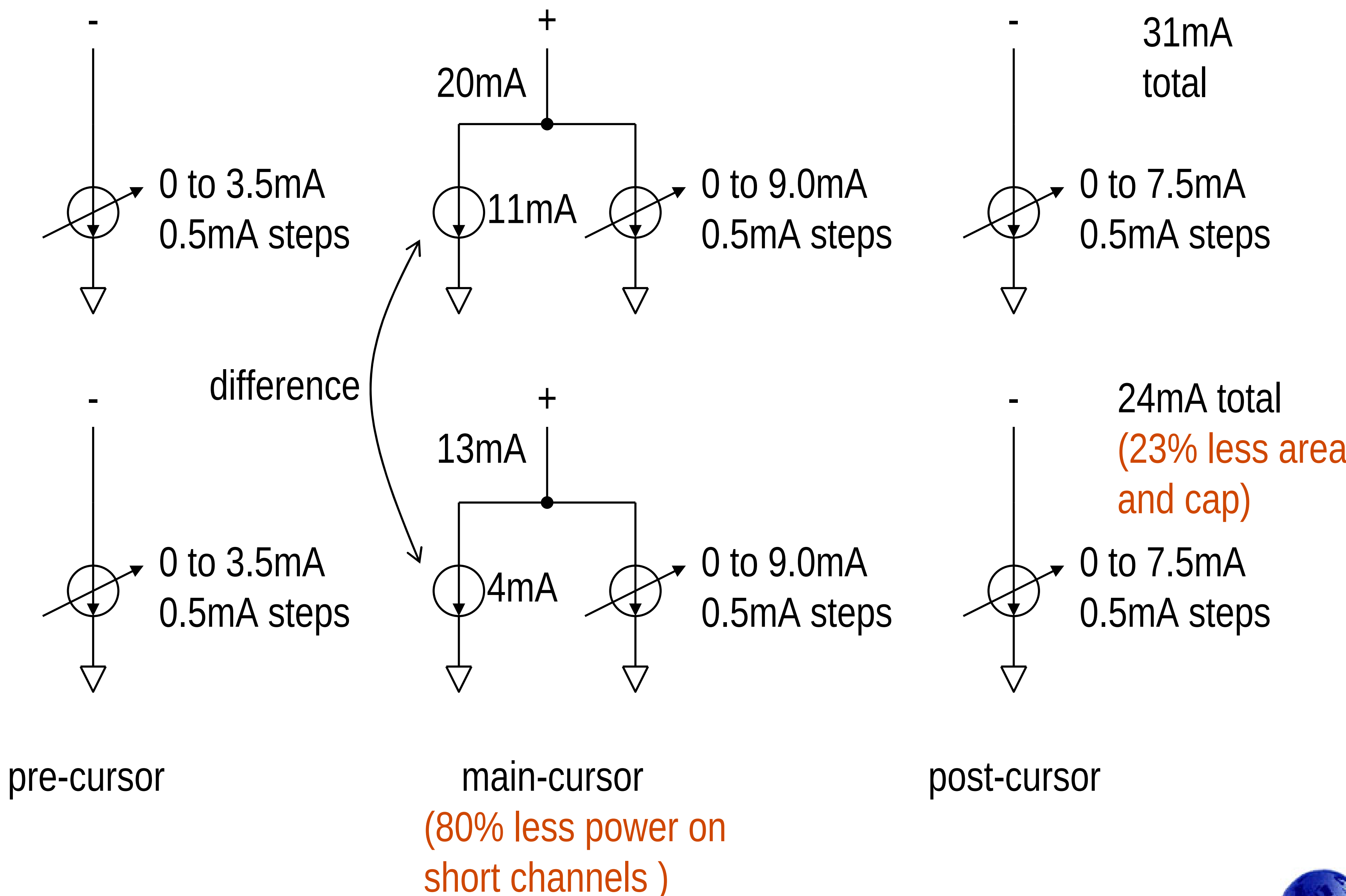
Constant Vss (200mV)

Representative tail-current based implementation



Circuit needs to be designed to support a total of 24.0mA

Max Power vs Constant Vss



Advantages of Constant Vss

- Not required to transmit at high power. We will have sensitive receivers. On most channels, maximum power is not needed to overcome receiver noise floor.
  - Lower crosstalk
  - Lower Tx power consumed (heat)
- Having to support a lower max current will allow smaller Tx devices.
  - Improved Tx return loss, less Tx reflections
- Reducing the Rx linearity requirement will allow smaller Rx devices and/or less current.
  - Improved Rx return loss, less Rx reflections
  - Lower Rx power consumed (heat)

Interoperability Concerns

- The TX is still capable of transmitting up to 1Vpp
  - It just has to be when equalization is applied
- Legacy 1G RX
  - Informative channel model loss at 622MHz = -5.6dB
  - 650mVpp TX => 375mVpp at RX
  - More complicating factors involved but reasonable signal level
- Will be capable of transmitting at most, 650 mVpp when transmitting to an OIF/CEI or PICMG receiver that is requesting no TX equalization.
- May not provide enough signal swing when on a short channel that is being subjected to cross talk from a legacy transmitter also on a short channel.

Conclusion

- Adopting a Constant Vss model for the TX equalizer offers a better overall system solution.
  - Lower Crosstalk
  - Lower Tx driver power (heat) (up to 80% less on short channels)
  - Lower TX area (up to 23% less TX driver fets and tail devices)
  - Lower Tx reflections (return loss) (up to 23% less drain and routing)
  - Lower Rx power (heat) (reduced linearity and dynamic range)
  - Lower Rx reflections (reduced linearity)
- We adopted the methodology of testing only the boundary of the TX equalizer. We still need only test the boundary, but it is recommended we test the 3-D boundary.
- Recommend we adopt a “Constant Vss” Tx equalizer model that provides sufficient interoperability performance.