Technique Used

1. Effect of substrate on Nsub.
2. Determine DT.
3. From data, determine total Q available for depletion.
4. Since Pdx. in Eq. tends to compensate substrate, any variation in Nsub must compensate part of Q put in to fix VT depl. So assume we can live with 10% or 15% (or 15, 25%) variation in Q & determine what kind of Nsub variation this translates to where
   \[ N_{sub} = \frac{Q}{X_f} \]
   when X_f is \( x \times 10^{-6} \) points (all of range).
5. Knowing various Nsubs one can calculate effect on VT from \( \frac{Q_b}{C_o} + 2Q_f \). What we then determine is the \( \Delta VT \) relative to \( N_{sub} \times 1.20 \) and \( N_{sub} \times 0.80 \) also from \( \pm 30\% \).
6. Since we need \( N_{sub} \geq 10^{16} \) for enhancement VT, we should with \( N_{sub} \geq 2.5 \times 10^{16} \pm 30\% \) and 7.5 E15 implants.
7. New VT's are calculated from \( \Delta VT \).
8. Then split \( \Delta VT \) by 2 and calculate current deviation as a function of Nsub variation. \( I = (V_{G} - V_T)^2 \)
9. Then check effect of Nsub variation on junction capacitance.
1. We need $10^{16}$ surface concentration to hit proper thresholds on enhancement devices.

2. We need considerably less dopant than this (2.5E15 $\rightarrow$ 6.2E12/cm) to be safe from a depletion spread point of view. However, we also play a tradeoff game with junction capacitance here as well.

<table>
<thead>
<tr>
<th>E.G.</th>
<th>$X_{\text{gate}}$</th>
<th>$C_{\text{ap}}$ @ 0V</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.2E14</td>
<td>n 2 n</td>
<td>&gt; 11 pF/nm</td>
</tr>
<tr>
<td>2.5E14</td>
<td>n 4 n</td>
<td>&gt; 0.55 pF/nm</td>
</tr>
</tbody>
</table>

3. Assumption is that $X_{\text{gate}}$ is critical and that all the caps introduced will be charged faster in depletion anyway.

So go with 2.5E15 starting (for $X_{\text{gate}}$) and replot another 2.5E15 to be 8

$V_{TE}$ @ $N = 10^{16}$ level.
$V_T$ variation vs. substrate doping variation

Variation assumed due to $\frac{0.5}{2} + 2P$.
Meeting 10/4/74

Non-related N⁺-N⁺ interconnects

\[ \text{VDD} \]

\[ \Phi_{MS} = -0.9 \text{V} \]

\[ \frac{\Phi_{SS}}{C} = 0.3 \]

\[ \frac{\Phi_{B}}{C_0} + 2\Phi_F = 2.1 \text{V}. \]

\[ 1.2 + \phi = 2.15 \text{V} \]

\[ V_B = 2.15 \text{V} \]

\[ V_B = 1.4 \text{V} \]

\[ I = K W L \left( V_G - V_T \right)^2 \cdot \frac{1.2 \text{V}}{2} \]

\[ \left( \frac{4.15}{3.55} \right)^2 \approx 1.37 \]

\[ K = k W N \]

\[ \text{VDD} \]
\[
\begin{align*}
\Delta C &= 1.8 \times 10^{15} \\
\Delta C &= 1.2 \times 10^{15} \\
\Delta C &= 1.5 \times 10^{15}
\end{align*}
\]

Total \( \Delta C \) permissible to maintain \( V_{DD} \) change in JFET.
Can't drive at the lightness. So we can use $10^{16}$ for incoming material.

\[ \text{65 cm} \times 2.5 \times 10^{15} \pm 30\% = 1.5 \times 10^{15} = \Delta \text{drain} \]

\[ 10 \Omega \cdot \text{cm} \times 1.5 \times 10^{15} \]

\[ 2 \times 10^{15} \text{ cm}^{-2} \]

\[ 10 \pm 30\% \]

\[ \text{Ordered:} \ 10 \Omega \cdot \text{cm} \pm 30\% \]

\[ 10^{16} \pm 0.075 \times 10^{16} = \text{concentration in enhancement mode device.} \]

\[ \Delta V_T = 0.13 \]

\[ \frac{Q}{3e[11]} = \frac{3e[11]}{V_{TH}} \]

\[ D_T = \frac{0.06 \times 35 \text{ cm}^2}{0.1 \times 10^{-2}} \]

\[ 2.5 \times 10^{15} = \frac{3e[11]}{V_{TH}} \]

\[ e^{v_0} = 1.7 \times 10^7 \text{ mV} \]

\[ v_0 = 1.7 \times 10^7 \times \frac{1}{10^{12}} = 1.7 \times 10^5 \text{ mV} \]

\[ x = 1.48 \times 10^{-4} \text{ cm}^2 = 5000 \text{ Å} \]

\[ 5 \times 10^{-4} \text{ cm}^2 = 6000 \text{ Å} \]

The $10^6$ implanted holes move $\pm 6$ kÅ into the field.

\[ \Omega \text{ implanted} = 3 \times 10^{-12} \]

Peak conc. after heat treatment

\[ Q = 8.55 \times 10^{-4} \]

\[ = 2.5 \times 10^5 \]

\[ = 5 \times 10^5 \]

\[ = 2.5 \times 10^6 \ 5 \times 10^6 \]