$$\frac{\delta}{\delta\beta}\sum_{i\ =\ 1}^{N}\left(y_i^* - X_i \times \beta\right)^2 = 0$$
$$\sum_{i\ =\ 1}^{N}\frac{\delta}{\delta\beta}\left(y_i^* - X_i \times \beta\right)^2 = 0$$
$$\sum_{i\ =\ 1}^{N} -2X_i\left(y_i^* - X_i \times \beta\right) = 0$$
$$2\sum_{i\ =\ 1}^{N} X_i\left(X_i \times \beta - y_i^*\right) = \ 0$$
$$\sum_{i\ =\ 1}^{N} X_i X_i \beta - \sum_{i\ =\ 1}^{N} X_i y_i^* = 0$$
$$X^T X\beta - X^T y^* = 0$$
$$X^T X\beta = X^T y^*$$
$$\left(X^T X\right)^{-1} X^T X\beta = \left(X^T X\right)^{-1} X^T y^*$$
$$\beta = \left(X^T X\right)^{-1} X^T y^*$$

$$\Sigma = \frac{1}{N}\left(\sum_{i:y_i^*=-1}(X_i - \mu_{-1})^T \times (X_i - \mu_{-1}) + \sum_{i:y_i^*=1}(X_i - \mu_1)^T \times (X_i - \mu_1)\right)$$

$$\Sigma = \tfrac{1}{N}(\textstyle\sum_{i:y_i^*=-1} X_i^T X - \sum_{i:y_i^*=-1} X_i^T \mu_{-1} - \sum_{i:y_i^*=-1} X_i \mu_{-1}^T + \sum_{i:y_i^*=-1} \mu_{-1}^T \mu_{-1}$$
$$+\textstyle\sum_{i:y_i^*=1} X_i^T X - \sum_{i:y_i^*=1} X_i^T \mu_1 - \sum_{i:y_i^*=1} X_i \mu_1^T + \sum_{i:y_i^*=1} \mu_1^T \mu_1)$$

Because the sum $\displaystyle\sum_{i:y_i^*=-1} X_i^T X + \sum_{i:y_i^*=1} X_i^T X$ covers every possible case in N,

this sum can be simplified as $\displaystyle\sum_{i=1}^{N} X_i^T X$.

$\displaystyle\mu_{-1} = \frac{1}{N_{-1}}\sum_{i:y_i^*=-1} X_i,\ \mu_1 = \frac{1}{N_1}\sum_{i:y_i^*=1} X_i$, and $N_{-1} = N_1 = \dfrac{N}{2}$ lead to

$$\sum_{i:y_i^*=-1} X_i^T \mu_{-1} + \sum_{i:y_i^*=1} X_i^T \mu_1 = \frac{2}{N}\sum_{i=1}^{N} X_i^T X.$$

$\displaystyle\frac{1}{N}(\sum_{i:y_i^*=-1}\mu_{-1}^T\mu_{-1} + \sum_{i:y_i^*=1}\mu_1^T\mu_1)$ simplifies to $\dfrac{1}{2}\left(\mu_{-1}^T\mu_{-1} + \mu_1^T\mu_1\right)$.

This leaves us with

$$\Sigma = (N-2)\sum_{i=1}^{N} X_i^T X - N\left(\sum_{i:y_i^*=-1} X_i \mu_{-1}^T + \sum_{i:y_i^*=1} X_i \mu_1^T\right) + \frac{1}{2}\left(\mu_{-1}^T\mu_{-1} + \mu_1^T\mu_1\right)$$

$$\Sigma = \frac{1}{N}\left(\sum_{i:y_i^*=-1}(X_i - \mu_{-1})^T \times (X_i - \mu_{-1}) + \sum_{i:y_i^*=1}(X_i - \mu_1)^T \times (X_i - \mu_1)\right)$$

$$\Sigma \times \beta + \frac{1}{4}(\mu_1 - \mu_{-1})^T \times (\mu_1 - \mu_{-1}) \times \beta = \frac{1}{2}(\mu_1 - \mu_{-1})$$