$$\log P(S) = \int_R f(y)dy$$

$$\frac{\partial}{\partial\theta} \log P(s) = \frac{\partial}{\partial\theta} \log \int_R \varphi(y;\theta,\Sigma)dy = \frac{1}{P(S)} \frac{\partial}{\partial\theta} P(S)$$

$$\frac{\partial}{\partial\theta} P(S) = \int_R \left(\Sigma^{-1}y - \Sigma^{-1}\theta\right) \varphi(y;\theta,\Sigma)dy$$

$$= P(S) \left(\Sigma^{-1}E(y|S) - \Sigma^{-1}\theta\right)$$

$$\Rightarrow \frac{\partial}{\partial\theta} \log P(s) = \Sigma^{-1}E(y|S) - \Sigma^{-1}\theta$$

$$\frac{\partial^2}{\partial\theta^2} \log P(S) = -\Sigma^{-1} + \frac{\partial}{\partial\theta}\Sigma^{-1}E(y|S)$$

$$\frac{\partial}{\partial\theta}E(y|S) = \int_R \frac{y}{P(S)^2} \left(P(S)(\Sigma^{-1}y - \Sigma^{-1}\theta)\varphi(y;\theta,\Sigma) - \varphi(y;\theta,\Sigma)P(S)(\Sigma^{-1}E(y|S) - \Sigma^{-1}\theta)\right)$$

$$= \int_R f(y|S)y \left(\Sigma^{-1}y - \Sigma^{-1}E(y|S)\right) dy = Var(y|S)\Sigma^{-1}$$

$$\Rightarrow \frac{\partial^2}{\partial\theta^2} \log P(S) = Var(\Sigma^{-1}y|S) - \Sigma^{-1}$$