# 1 SchemeHIBME

This scheme is applicable to symmetric and asymmetric groups of prime orders.

## 1.1 Setup($l$) $\rightarrow$ ($\boldsymbol{mpk}$, $\boldsymbol{msk}$)

$g \leftarrow 1_{\mathbb{G}_1}$
generate $\alpha, b_1, b_2 \in \mathbb{Z}_r$ randomly
generate $s_1, s_2, \cdots, s_l, a_1, a_2, \cdots, a_l \in \mathbb{Z}_r$ randomly
generate $g_2, g_3 \in \mathbb{G}_2$ randomly
generate $h_1, h_2, \cdots, h_l \in \mathbb{G}_2$ randomly (Note that the indexes in implementations are 1 smaller than those in theory)
$H_1 : \mathbb{Z}_r \rightarrow \mathbb{G}_1$
$H_2 : \mathbb{Z}_r \rightarrow \mathbb{G}_2$
$\hat{H} : \{0,1\}^* \rightarrow \{0,1\}^\lambda$
$g_1 \leftarrow g^\alpha$
$A \leftarrow e(g_1, g_2)$
$\bar{g} \leftarrow g^{b_1}$
$\tilde{g} \leftarrow g^{b_2}$
$\bar{g}_3 \leftarrow g_3^{\frac{1}{b_1}}$
$\tilde{g}_3 \leftarrow g_3^{\frac{1}{b_2}}$
$mpk \leftarrow (g, g_1, g_2, g_3, \bar{g}, \tilde{g}, \bar{g}_3, \tilde{g}_3, h_1, h_2, \cdots, h_l, H_1, H_2, \hat{H}, A)$
$msk \leftarrow (g_2^\alpha, b_1, b_2, s_1, s_2, \cdots, s_l, a_1, a_2, \cdots, a_l)$
**return** $(mpk, msk)$

## 1.2 EKGen($\boldsymbol{ID}_k$) $\rightarrow$ $\boldsymbol{ek}_{\boldsymbol{ID}_k}$

$A_k \leftarrow \prod_{j=1}^{k} a_j$
$ek_{1,i} \leftarrow H_1(I_i)^{s_i A_k}, \forall i \in \{1, 2, \cdots, k\}$
$ek_{2,i} \leftarrow s_{k+i} A_k, \forall i \in \{1, 2, \cdots, l-k\}$
$ek_3 \leftarrow (a_{k+1}, a_{k+2}, \cdots, a_l)$
$ek_{ID_k} \leftarrow (ek_1, ek_2, ek_3)$
**return** $ek_{ID_k}$

## 1.3 DerivedEKGen($\boldsymbol{ek}_{\boldsymbol{ID}_{k-1}}$, $\boldsymbol{ID}_k$) $\rightarrow$ $\boldsymbol{ek}_{\boldsymbol{ID}_k}$

$ek'_{1,i} \leftarrow ek_{1,i}^{a_k}, \forall i \in \{1, 2, \cdots, k-1\}$
$ek'_{1,k} \leftarrow H_1(I_k)^{ek_{2,1} a_k}$
$ek'_1 \leftarrow ek'_1 || \langle ek'_{1,k} \rangle$
$ek'_{2,i} \leftarrow ek_{2,i} \cdot a_k, \forall i \in \{2, 3, \cdots, l-k+1\}$
$ek'_3 \leftarrow (a_{k+1}, a_{k+2}, \cdots, a_l)$
$ek_{ID_k} \leftarrow (ek'_1, ek'_2, ek'_3)$
**return** $ek_{ID_k}$

## 1.4 DKGen($\boldsymbol{ID}_k$) $\rightarrow$ $\boldsymbol{dk}_{\boldsymbol{ID}_k}$

generate $r \in \mathbb{Z}_r$ randomly
$HI \leftarrow h_1^{I_1} h_2^{I_2} \cdots h_k^{I_k}$
$a_0 \leftarrow g_2^{\frac{\alpha}{b_1}} \cdot HI^{\frac{r}{b_1}} \cdot \bar{g}_3^r$
$a_1 \leftarrow g_2^{\frac{\alpha}{b_2}} \cdot HI^{\frac{r}{b_2}} \cdot \tilde{g}_3^r$
$A_k \leftarrow \prod_{j=1}^{k} a_j$
$dk_1 \leftarrow (a_0, a_1, g^r, h_{k+1}^{\frac{r}{b_1}}, h_{k+2}^{\frac{r}{b_1}}, \cdots, h_l^{\frac{r}{b_1}}, h_{k+1}^{\frac{r}{b_2}}, h_{k+2}^{\frac{r}{b_2}}, \cdots, h_l^{\frac{r}{b_2}}, h_{k+1}^{b_1^{-1}}, h_{k+2}^{b_1^{-1}}, \cdots, h_l^{b_1^{-1}},$
$h_{k+1}^{b_2^{-1}}, h_{k+2}^{b_2^{-1}}, \cdots, h_2^{b_1^{-1}}, HI^{\frac{1}{b_1}}, HI^{\frac{1}{b_2}})$
$dk_{2,i} \leftarrow H_2(I_i)^{s_i A_k}, \forall i \in \{1, 2, \cdots, k\}$
$dk_{3,i} \leftarrow s_{k+i} A_k, \forall i \in \{1, 2, \cdots, l-k\}$
$dk_4 \leftarrow (a_{k+1}, a_{k+2}, \cdots, a_l)$
$dk_{ID_k} \leftarrow (dk_1, dk_2, dk_3, dk_4)$
**return** $dk_{ID_k}$

## 1.5 DerivedDKGen($\boldsymbol{dk}_{\boldsymbol{ID}_{k-1}}, \boldsymbol{ID}_k$) $\rightarrow$ $\boldsymbol{dk}_{\boldsymbol{ID}_k}$

generate $t \in \mathbb{Z}_r$ randomly
$a'_0 \leftarrow a_0 \cdot c_{0,k}^{I_k} \cdot (f_0 \cdot d_{0,k}^{I_k} \cdot \bar{g}_3)^t$
$a'_1 \leftarrow a_1 \cdot c_{1,k}^{I_k} \cdot (f_1 \cdot d_{1,k}^{I_k} \cdot \tilde{g}_3)^t$
$dk'_1 \leftarrow (a'_0, a'_1, b \cdot g^t, c_{0,k+1} \cdot d_{0,k+1}^t, c_{0,k+2} \cdot d_{0,k+2}^t, \cdots, c_{0,l} \cdot d_{0,l}^t, c_{1,k+1} \cdot d_{1,k+1}^t, c_{1,k+2} \cdot$
$d_{1,k+2}^t, \cdots, c_{1,l} \cdot d_{1,l}^t, d_{0,k+1}, d_{0,k+2}, \cdots, d_{0,l}, d_{1,k+1}, d_{1,k+2}, \cdots, d_{1,l}, f_0 \cdot c_{0,k}^{I_k}, f_1 \cdot$
$c_{1,k}^{I_k})$
$dk'_{2,i} \leftarrow dk_{2,i}^{a_k}, \forall i \in \{1, 2, \cdots, k-1\}$
$dk'_{2,k} \leftarrow H_2(I_k)^{dk_{3,1} a_k}$
$dk'_2 \leftarrow dk'_2 || \langle dk'_{2,k} \rangle$
$dk'_{3,i} \leftarrow dk_{3,i} \cdot a_k, \forall i \{2, 3, \cdots, l-k+1\}$
$dk'_4 \leftarrow (a_{k+1}, a_{k+2}, \cdots, a_l)$
$dk_{ID_k} \leftarrow (dk'_1, dk'_2, dk'_3, dk'_4)$
**return** $dk_{ID_k}$

## 1.6 Enc($\boldsymbol{ek}_{\boldsymbol{ID}_S}, \boldsymbol{ID}_{\boldsymbol{Rev}}, M$) $\rightarrow$ $\boldsymbol{CT}$

generate $s_1, s_2, \eta \in \mathbb{Z}_r$ randomly
$T \leftarrow A^{s_1+s_2}$
**if** $m = n$ **then**
  $K \leftarrow \prod_{i=1}^{n} e(g^\eta \cdot ek_{1,i}, H_2(I'_i))$
**else if** $m > n$ **then**
  $A_n \leftarrow \prod_{i=1}^{n} a_i$
  $B_n^m \leftarrow \prod_{i=n+1}^{m} a_i$
  $K \leftarrow (\prod_{i=1}^{n} e(ek_{1,i}, H_2(I'_i)) \cdot \prod_{i=n+1}^{m} e(H_1(I_n), H_2(I'_i))^{s_i A_n})^{B_n^m} \cdot e(g^\eta, \prod_{i=1}^{m} H_2(I'_i))$
**else if** $m < n$ **then**

$$K \leftarrow \prod_{i=1}^{m} e(ek_{1,i}, H_2(I'_i)) \prod_{i=m+1}^{n} e(ek_{1,i}, H_2(I'_m))e(g^{\eta}, \prod_{i=1}^{m} H_2(I'_i))$$

$C_1 \leftarrow M \oplus \hat{H}(T) \oplus \hat{H}(K)$
$C_2 \leftarrow \bar{g}^{s_1}$
$C_3 \leftarrow \tilde{g}^{s_2}$
$C_4 \leftarrow (h_1^{I_1} h_2^{I_2} \cdots h_n^{I_n} \cdot g_3)^{s_1+s_2}$
$C_5 \leftarrow g^{\eta}$
$CT \leftarrow (C_1, C_2, C_3, C_4, C_5)$
**return** $CT$

## 1.7 $\mathbf{Dec}(\boldsymbol{dk_{ID_R}}, \boldsymbol{ID_{Rev}}, \boldsymbol{ID_{Snd}}, \boldsymbol{CT}) \rightarrow M$

$$T' = \frac{e(dk_{1,3}, C_4)}{e(C_2, dk_{1,1})e(C_3, dk_{1,2})}$$

**if** $m = n$ **then**

$$K' \leftarrow \prod_{i=1}^{n} e(H_1(I_i), dk_{2,i}) \cdot e(C_5, \prod_{i=1}^{n} H_2(I'_i))$$

**else if** $m > n$ **then**

$$K' \leftarrow \prod_{i=1}^{n} e(H_1(I_i), dk_{2,i}) \cdot \prod_{i=n+1}^{m} e(H_1(I_n), dk_{2,i}) \cdot e(C_5, \prod_{i=1}^{m} H_2(I'_i))$$

**else if** $m < n$ **then**

$$A_m \leftarrow \prod_{i=1}^{m} a_i$$

$$B_n^m \leftarrow \prod_{i=m+1}^{n} a_i$$

$$K' \leftarrow (\prod_{i=1}^{m} e(H_1(I_i), dk_{2,i}) \cdot \prod_{i=m+1}^{n} e(H_1(I_i), H_2(I'_m))^{s_i A_m})^{B_m^n} \cdot e(C_5, \prod_{i=1}^{m} H_2(I'_i))$$

$M \leftarrow C_1 \oplus \hat{H}(T') \oplus \hat{H}(K')$
**return** $M$