This website contains FORM programs which evaluate the one and two-loop β-functions for the R-parity violating (RPV) version of the Minimal Supersymmetric Standard Model (MSSM). The β-functions are evaluated using the DRED'regularisation scheme[1]. The programs are easily adaptable to include different subsets of the RPV couplings. The FORM package is publicly available at http://www.nikhef.nl/form. Once FORM is installed and you have downloaded the three programs rgvmaster.frm, masterdec.h and zeros.h from this website, you can run the program by typing:

form3 -l rgvmaster

The output then appears (after a delay which may be considerable depending on how many couplings have been included) in the file rgvmaster.log. This file also includes extraneous output such as a copy of the program; the start of the output β-functions may be found by searching for "betag1one =". (Note the space!) The anomalous dimensions for the Higgs fields are also included since they are required for the running of the vevs v_1 and v_2.

The programs in principle produce results for the most general RPV version of the MSSM incorporating the "standard" soft-breaking terms[1], including the most general sets of (*real*) Yukawa and soft-breaking couplings and masses in flavour space. The set of couplings in which you are interested may be specified by editing the file zeros.h. The default here is that all couplings are set to zero. A non-zero coupling may be selected by putting a "*" at the start of the corresponding line so that FORM will ignore it. Thus "yu33=0;" would set the top Yukawa zero but "*yu33=0;" would retain it.

In these instructions we start by defining our notation for the RPV MSSM. We then explain how the various couplings are represented in the FORM program and also how the various β-functions are represented in the output.

The unbroken $\mathcal{N}=1$ theory is defined by the superpotential

$$W = W_1 + W_2, \tag{1}$$

where

$$W_1 = Y_u Q u^c H_2 + Y_d Q d^c H_1 + Y_e L e^c H_1 + \mu H_1 H_2 \tag{2}$$

and

$$W_2 = \tfrac{1}{2}(\Lambda_E) e^c LL + \tfrac{1}{2}(\Lambda_U) u^c d^c d^c + (\Lambda_D) d^c LQ + \kappa_i L_i H_2. \tag{3}$$

[1] See for instance Ref. [2] for a discussion of the possible non-standard soft terms

In these equations, generation $(i, j \cdots)$, $SU_2(a, b \cdots)$, and $SU_3(\alpha, \beta \cdots)$ indices are contracted in "natural" fashion from left to right, thus for example

$$\Lambda_D d^c L Q \equiv \epsilon_{ab} (\Lambda_D)^{ijk} (d^c)_{i\alpha} L^a_j Q^{b\alpha}_k . \tag{4}$$

For the generation indices we indicate complex conjugation by lowering the indices, thus $(Y_u)_{ij} = (Y_u^*)^{ij}$. We now add soft-breaking terms as follows:

$$\begin{aligned} L_1 &= \sum_\phi m_\phi^2 \phi^* \phi + \left[B H_1 H_2 + \sum_{i=1}^{3} \tfrac{1}{2} M_i \lambda_i \lambda_i + \text{h.c.} \right] \\ &\quad + \left[h_u Q u^c H_2 + h_d Q d^c H_1 + h_e L e^c H_1 + \text{h.c.} \right], \\ L_2 &= m_R^2 H_1^* L + m_K^2 L H_2 + \tfrac{1}{2} h_E e^c L L + \tfrac{1}{2} h_U u^c d^c d^c + h_D d^c L Q + \text{h.c.} \end{aligned} \tag{5}$$

We shall also use the notation

$$\lambda^{ijk} = (\Lambda_E)^{kij}\,, \quad \lambda'^{ijk} = (\Lambda_D)^{kij}\,, \quad \lambda''^{ijk} = (\Lambda_U)^{ijk}\,, \tag{6}$$

with h, h' and h'' defined similarly in terms of h_E, h_D and h_U respectively. Note that

$$\lambda^{jik} = -\lambda^{ijk}, \quad \lambda''^{ikj} = -\lambda''^{ijk}, \tag{7}$$

with similar symmetry properties for h and h''. In the program we use the notation:

$$\begin{gathered} g_1 \Rightarrow \text{g1}, \quad g_2 \Rightarrow \text{g2}, \quad g_3 \Rightarrow \text{g3}, \\ Y_u^{ij} \Rightarrow \text{yu}ij\text{Q}, \quad Y_d^{ij} \Rightarrow \text{yd}ij\text{Q}, \quad Y_e^{ij} \Rightarrow \text{ye}ij\text{Q}, \\ h_u^{ij} \Rightarrow \text{hu}ij\text{Q}, \quad h_d^{ij} \Rightarrow \text{hd}ij\text{Q}, \quad h_e^{ij} \Rightarrow \text{he}ij\text{Q}, \\ \Lambda_E^{ijk} \Rightarrow \text{le}ijk\text{Q}, \quad \Lambda_D^{ijk} \Rightarrow \text{ld}ijk\text{Q}, \quad \Lambda_U^{ijk} \Rightarrow \text{lu}ijk\text{Q}, \\ h_E^{ijk} \Rightarrow \text{hle}ijk\text{Q}, \quad h_D^{ijk} \Rightarrow \text{hld}ijk\text{Q}, \quad h_U^{ijk} \Rightarrow \text{hlu}ijk\text{Q}, \\ M_1 \Rightarrow \text{M1}, \quad M_2 \Rightarrow \text{M2}, \quad M_3 \Rightarrow \text{M3}, \quad \mu \Rightarrow \text{mu}, \\ (m_Q^2)^i{}_j \Rightarrow \text{mq}ij\text{Q}, \quad (m_u^2)^i{}_j \Rightarrow \text{mu}ij\text{Q}, \quad (m_d^2)^i{}_j \Rightarrow \text{md}ij\text{Q} \\ (m_L^2)^i{}_j \Rightarrow \text{ml}ij\text{Q}, \quad (m_e^2)^i{}_j \Rightarrow \text{me}ij\text{Q}, \quad (m_R^2)^i \Rightarrow \text{mr}i\text{Q}, \quad B \Rightarrow \text{B}, \\ \kappa^i \Rightarrow \text{k}i\text{Q}, \quad \left(m_K^2\right)^i \Rightarrow \text{mk}i \end{gathered} \tag{8}$$

so that Y_u^{23} is denoted yu23Q. The Q ending is introduced to allow easy global editing of the couplings; for instance, to produce output suitable for a Maple program one may want to change yu23Q to yu23(t) etc.

The β-functions are given in similar form; for instance

$$
\begin{aligned}
\beta_{g_1}^{(1)} &\Rightarrow \text{betag1one} \\
\beta_{g_2}^{(1)} &\Rightarrow \text{betag2one} \\
\beta_{g_3}^{(1)} &\Rightarrow \text{betag3one} \\
\left(\beta_{Y^u}^{(1)}\right)^{i}{}_{j} &\Rightarrow \text{betayu}ij\text{one} \\
\left(\beta_{Y^d}^{(1)}\right)^{i}{}_{j} &\Rightarrow \text{betayd}ij\text{one} \\
\left(\beta_{Y^e}^{(1)}\right)^{i}{}_{j} &\Rightarrow \text{betaye}ij\text{one} \\
\left(\beta_{\Lambda_E}^{(1)}\right)^{ijk} &\Rightarrow \text{betale}ijk\text{one} \\
\left(\beta_{\Lambda_D}^{(1)}\right)^{ijk} &\Rightarrow \text{betald}ijk\text{one} \\
\left(\beta_{\Lambda_U}^{(1)}\right)^{ijk} &\Rightarrow \text{betalu}ijk\text{one} \\
\left(\beta_{h^u}^{(1)}\right)^{i}{}_{j} &\Rightarrow \text{betahu}ij\text{one} \\
\left(\beta_{h^d}^{(1)}\right)^{i}{}_{j} &\Rightarrow \text{betahd}ij\text{one} \\
\left(\beta_{h^e}^{(1)}\right)^{i}{}_{j} &\Rightarrow \text{betahe}ij\text{one} \\
\left(\beta_{h_E}^{(1)}\right)^{ijk} &\Rightarrow \text{betale}ijk\text{one} \\
\left(\beta_{h_D}^{(1)}\right)^{ijk} &\Rightarrow \text{betald}ijk\text{one} \\
\left(\beta_{h_U}^{(1)}\right)^{ijk} &\Rightarrow \text{betalu}ijk\text{one} \\
\beta_{M_1}^{(1)} &\Rightarrow \text{betaM1one} \\
\beta_{M_2}^{(1)} &\Rightarrow \text{betaM2one} \\
\beta_{M_3}^{(1)} &\Rightarrow \text{betaM3one} \\
\gamma_{H_1}^{(1)} &\Rightarrow \text{gh1one} \\
\gamma_{H_2}^{(1)} &\Rightarrow \text{gh2one} \\
\beta_{\mu}^{(1)} &\Rightarrow \text{betamuone} \\
\left(\beta_{m_Q^2}^{(1)}\right)^{i}{}_{j} &\Rightarrow \text{betamq}ij\text{one} \\
\left(\beta_{m_u^2}^{(1)}\right)^{i}{}_{j} &\Rightarrow \text{betamu}ij\text{one} \\
\left(\beta_{m_d^2}^{(1)}\right)^{i}{}_{j} &\Rightarrow \text{betamd}ij\text{one} \\
\left(\beta_{m_L^2}^{(1)}\right)^{i}{}_{j} &\Rightarrow \text{betaml}ij\text{one} \\
\left(\beta_{m_e^2}^{(1)}\right)^{i}{}_{j} &\Rightarrow \text{betame}ij\text{one} \\
\beta_{m_{H_1}^2}^{(1)} &\Rightarrow \text{betamh1one} \\
\beta_{m_{H_2}^2}^{(1)} &\Rightarrow \text{betamh2one} \\
\left(\beta_{m_R^2}^{(1)}\right)^{i} &\Rightarrow \text{betamr}i\text{one} \\
\left(\beta_{\kappa}^{(1)}\right)^{i} &\Rightarrow \text{betak}i\text{one} \\
\left(\beta_{B}^{(1)}\right) &\Rightarrow \text{betaBone} \\
\left(\beta_{m_K^2}^{(1)}\right)^{i} &\Rightarrow \text{betamk}i\text{one}
\end{aligned}
\tag{9}
$$

The two-loop β-functions are similarly defined by replacing “one” by “two” on the right-hand side of Eq. (9).