

Yarıiletken Elemanların ve Düzenlerin Modellenmesi

Ödev 2

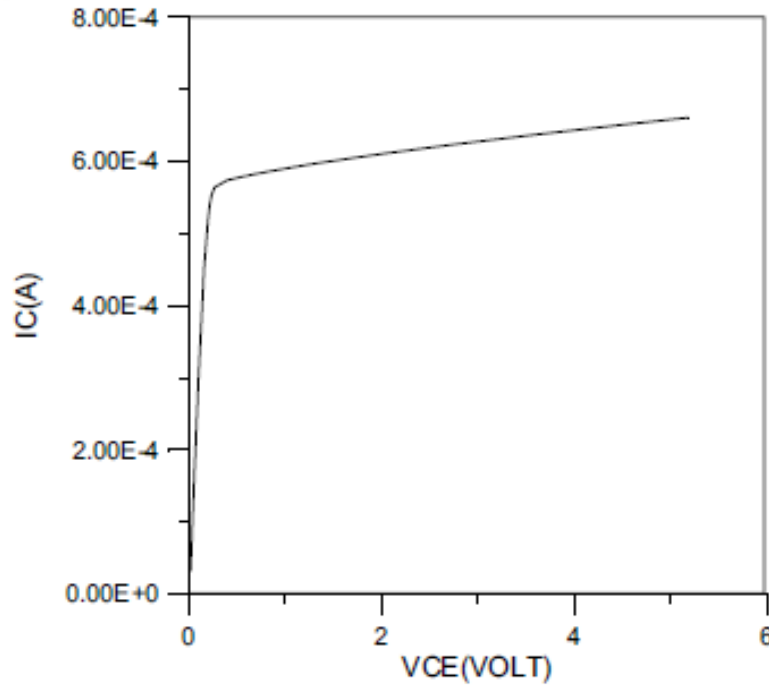
Veriliş tarihi: 14.11.2015, (süre 2 hafta)

Bir npn transistor için baz-emetör gerilimi $V_{BE} = 0.7V$ değerinde sabit tutularak ölçüm sonucu elde edilmiş olan çıkış özeğrisi Şekil-1 ve ölçüm verileri de Tablo 1'de verilmiştir. Bu çıkış karakteristiğini (ve ölçüm verilerini) kullanarak söz konusu npn tranzistor için m_C kolektör-baz jonksiyonu kapasite gradyan faktörünü ve M_F ileri yönde Early çarpanını belirleyiniz. $I_S = 1.2 \times 10^{-15}A$, $\Phi_C = 0.8V$ olarak belirlenmiştir.

Yol gösterme:

- Bunun için çıkış özeğrisi üzerinde seçilen çalışma noktalarında her bir çalışma noktası için alacağınız küçük ΔV_{CE} değişimlerinden ve bunlara karşı düşen ΔI_C değişimlerinden yararlanarak $y_{oe} = \Delta I_C / \Delta V_{CE}$ çıkış iletkenliğinin V_{CE} gerilimiyle değişimini elde ediniz. Buradan yararlanarak m_C parametresini belirleyiniz.
- Çıkış karakteristiği üzerinde seçilen noktalardan hareketle M_F ileri yönde Early çarpanının nasıl belirleneceğini araştırınız. M_F Early çarpanını eğri üzerinde seçilen akım ve gerilim değerlerine bağlayan bağıntıyı çıkartınız.

Elde ettiğiniz model parametrelerini kullanarak hesap sonucu elde edeceğiniz $I_C = I_C(V_{CE})$ değişimleri verilen ölçüm sonuçlarıyla karşılaştırarak aradaki farkları yorumlayınız.



Şekil-1 npn transistor için ölçüm yoluyla belirlenmiş olan $I_C = I_C(V_{CE})$ değişimi. $V_{BE} = 0.7V$ değerinde sabit tutulmuştur.

VCE (V)	IC (A)
2.000000e-002	3.219990e-005
3.000000e-002	6.658257e-005
4.000000e-002	1.005492e-004
5.000000e-002	1.340489e-004
6.000000e-002	1.670285e-004
7.000000e-002	1.994320e-004
8.000000e-002	2.311904e-004
9.000000e-002	2.622232e-004
1.000000e-001	2.924374e-004
1.100000e-001	3.217275e-004
1.200000e-001	3.499687e-004
1.300000e-001	3.770205e-004
1.400000e-001	4.027267e-004
1.500000e-001	4.269111e-004
1.600000e-001	4.493903e-004
1.700000e-001	4.699767e-004
1.800000e-001	4.884968e-004
1.900000e-001	5.048104e-004
2.000000e-001	5.188437e-004
2.100000e-001	5.306042e-004
2.200000e-001	5.402020e-004
2.300000e-001	5.478320e-004
2.400000e-001	5.537602e-004
2.500000e-001	5.582865e-004
2.600000e-001	5.616992e-004
2.700000e-001	5.642580e-004
2.800000e-001	5.661844e-004
2.900000e-001	5.676440e-004
3.000000e-001	5.687720e-004
3.100000e-001	5.696590e-004
3.200000e-001	5.703837e-004
3.300000e-001	5.709868e-004
3.400000e-001	5.715130e-004
3.500000e-001	5.719750e-004
3.600000e-001	5.723959e-004
3.700000e-001	5.727891e-004
3.800000e-001	5.731620e-004
3.900000e-001	5.735201e-004
4.000000e-001	5.738675e-004
4.100000e-001	5.742069e-004
4.200000e-001	5.745401e-004
4.300000e-001	5.748685e-004
4.400000e-001	5.751924e-004
4.500000e-001	5.755118e-004
4.600000e-001	5.758273e-004
4.700000e-001	5.761394e-004
4.800000e-001	5.764483e-004
4.900000e-001	5.767543e-004
5.000000e-001	5.770576e-004
5.100000e-001	5.773583e-004
5.200000e-001	5.776566e-004

VCE (V)	IC (A)
5.300000e-001	5.779525e-004
5.400000e-001	5.782461e-004
5.500000e-001	5.785376e-004
5.600000e-001	5.788270e-004
5.700000e-001	5.791143e-004
5.800000e-001	5.793997e-004
5.900000e-001	5.796831e-004
6.000000e-001	5.799647e-004
6.100000e-001	5.802444e-004
6.200000e-001	5.805224e-004
6.300000e-001	5.807987e-004
6.400000e-001	5.810732e-004
6.500000e-001	5.813462e-004
6.600000e-001	5.816175e-004
6.700000e-001	5.818872e-004
6.800000e-001	5.821555e-004
6.900000e-001	5.824222e-004
7.000000e-001	5.826874e-004
7.100000e-001	5.829513e-004
7.200000e-001	5.832137e-004
7.300000e-001	5.834747e-004
7.400000e-001	5.837345e-004
7.500000e-001	5.839928e-004
7.600000e-001	5.842499e-004
7.700000e-001	5.845058e-004
7.800000e-001	5.847604e-004
7.900000e-001	5.850138e-004
8.000000e-001	5.852659e-004
8.100000e-001	5.855170e-004
8.200000e-001	5.857668e-004
8.300000e-001	5.860156e-004
8.400000e-001	5.862632e-004
8.500000e-001	5.865098e-004
8.600000e-001	5.867553e-004
8.700000e-001	5.869997e-004
8.800000e-001	5.872431e-004
8.900000e-001	5.874855e-004
9.000000e-001	5.877269e-004
9.100000e-001	5.879674e-004
9.200000e-001	5.882069e-004
9.300000e-001	5.884454e-004
9.400000e-001	5.886830e-004
9.500000e-001	5.889197e-004
9.600000e-001	5.891554e-004
9.700000e-001	5.893903e-004
9.800000e-001	5.896244e-004
9.900000e-001	5.898575e-004
1.000000e+000	5.900899e-004
1.010000e+000	5.903214e-004
1.020000e+000	5.905520e-004
1.030000e+000	5.907819e-004

VCE (V)	IC (A)
1.040000e+000	5.910110e-004
1.050000e+000	5.912392e-004
1.060000e+000	5.914668e-004
1.070000e+000	5.916935e-004
1.080000e+000	5.919195e-004
1.090000e+000	5.921448e-004
1.100000e+000	5.923693e-004
1.110000e+000	5.925931e-004
1.120000e+000	5.928162e-004
1.130000e+000	5.930386e-004
1.140000e+000	5.932604e-004
1.150000e+000	5.934814e-004
1.160000e+000	5.937017e-004
1.170000e+000	5.939214e-004
1.180000e+000	5.941405e-004
1.190000e+000	5.943589e-004
1.200000e+000	5.945767e-004
1.210000e+000	5.947938e-004
1.220000e+000	5.950103e-004
1.230000e+000	5.952262e-004
1.240000e+000	5.954415e-004
1.250000e+000	5.956562e-004
1.260000e+000	5.958703e-004
1.270000e+000	5.960838e-004
1.280000e+000	5.962967e-004
1.290000e+000	5.965091e-004
1.300000e+000	5.967209e-004
1.310000e+000	5.969322e-004
1.320000e+000	5.971428e-004
1.330000e+000	5.973530e-004
1.340000e+000	5.975626e-004
1.350000e+000	5.977717e-004
1.360000e+000	5.979803e-004
1.370000e+000	5.981883e-004
1.380000e+000	5.983958e-004
1.390000e+000	5.986029e-004
1.400000e+000	5.988094e-004
1.410000e+000	5.990154e-004
1.420000e+000	5.992209e-004
1.430000e+000	5.994260e-004
1.440000e+000	5.996305e-004
1.450000e+000	5.998346e-004
1.460000e+000	6.000382e-004
1.470000e+000	6.002414e-004
1.480000e+000	6.004441e-004
1.490000e+000	6.006463e-004
1.500000e+000	6.008481e-004
1.510000e+000	6.010495e-004
1.520000e+000	6.012504e-004
1.530000e+000	6.014508e-004
1.540000e+000	6.016508e-004

VCE (V)	IC (A)
1.550000e+000	6.018504e-004
1.560000e+000	6.020496e-004
1.570000e+000	6.022484e-004
1.580000e+000	6.024467e-004
1.590000e+000	6.026446e-004
1.600000e+000	6.028422e-004
1.610000e+000	6.030393e-004
1.620000e+000	6.032360e-004
1.630000e+000	6.034323e-004
1.640000e+000	6.036282e-004
1.650000e+000	6.038238e-004
1.660000e+000	6.040189e-004
1.670000e+000	6.042137e-004
1.680000e+000	6.044081e-004
1.690000e+000	6.046021e-004
1.700000e+000	6.047958e-004
1.710000e+000	6.049890e-004
1.720000e+000	6.051820e-004
1.730000e+000	6.053745e-004
1.740000e+000	6.055667e-004
1.750000e+000	6.057586e-004
1.760000e+000	6.059501e-004
1.770000e+000	6.061412e-004
1.780000e+000	6.063320e-004
1.790000e+000	6.065225e-004
1.800000e+000	6.067126e-004
1.810000e+000	6.069024e-004
1.820000e+000	6.070918e-004
1.830000e+000	6.072809e-004
1.840000e+000	6.074697e-004
1.850000e+000	6.076582e-004
1.860000e+000	6.078463e-004
1.870000e+000	6.080342e-004
1.880000e+000	6.082217e-004
1.890000e+000	6.084089e-004
1.900000e+000	6.085958e-004
1.910000e+000	6.087823e-004
1.920000e+000	6.089686e-004
1.930000e+000	6.091546e-004
1.940000e+000	6.093403e-004
1.950000e+000	6.095256e-004
1.960000e+000	6.097107e-004
1.970000e+000	6.098955e-004
1.980000e+000	6.100800e-004
1.990000e+000	6.102642e-004
2.000000e+000	6.104481e-004
2.010000e+000	6.106317e-004
2.020000e+000	6.108150e-004
2.030000e+000	6.109981e-004
2.040000e+000	6.111809e-004
2.050000e+000	6.113634e-004

VCE (V)	IC (A)
2.060000e+000	6.115456e-004
2.070000e+000	6.117276e-004
2.080000e+000	6.119093e-004
2.090000e+000	6.120907e-004
2.100000e+000	6.122719e-004
2.110000e+000	6.124528e-004
2.120000e+000	6.126334e-004
2.130000e+000	6.128138e-004
2.140000e+000	6.129939e-004
2.150000e+000	6.131738e-004
2.160000e+000	6.133534e-004
2.170000e+000	6.135327e-004
2.180000e+000	6.137119e-004
2.190000e+000	6.138907e-004
2.200000e+000	6.140693e-004
2.210000e+000	6.142477e-004
2.220000e+000	6.144258e-004
2.230000e+000	6.146037e-004
2.240000e+000	6.147814e-004
2.250000e+000	6.149588e-004
2.260000e+000	6.151359e-004
2.270000e+000	6.153129e-004
2.280000e+000	6.154896e-004
2.290000e+000	6.156661e-004
2.300000e+000	6.158423e-004
2.310000e+000	6.160183e-004
2.320000e+000	6.161941e-004
2.330000e+000	6.163697e-004
2.340000e+000	6.165450e-004
2.350000e+000	6.167202e-004
2.360000e+000	6.168951e-004
2.370000e+000	6.170697e-004
2.380000e+000	6.172442e-004
2.390000e+000	6.174185e-004
2.400000e+000	6.175925e-004
2.410000e+000	6.177663e-004
2.420000e+000	6.179399e-004
2.430000e+000	6.181133e-004
2.440000e+000	6.182865e-004
2.450000e+000	6.184595e-004
2.460000e+000	6.186323e-004
2.470000e+000	6.188049e-004
2.480000e+000	6.189773e-004
2.490000e+000	6.191494e-004
2.500000e+000	6.193214e-004
2.510000e+000	6.194932e-004
2.520000e+000	6.196648e-004
2.530000e+000	6.198361e-004
2.540000e+000	6.200073e-004
2.550000e+000	6.201783e-004
2.560000e+000	6.203491e-004

VCE (V)	IC (A)
2.570000e+000	6.205197e-004
2.580000e+000	6.206901e-004
2.590000e+000	6.208604e-004
2.600000e+000	6.210304e-004
2.610000e+000	6.212003e-004
2.620000e+000	6.213699e-004
2.630000e+000	6.215394e-004
2.640000e+000	6.217087e-004
2.650000e+000	6.218778e-004
2.660000e+000	6.220468e-004
2.670000e+000	6.222155e-004
2.680000e+000	6.223841e-004
2.690000e+000	6.225525e-004
2.700000e+000	6.227207e-004
2.710000e+000	6.228888e-004
2.720000e+000	6.230566e-004
2.730000e+000	6.232243e-004
2.740000e+000	6.233919e-004
2.750000e+000	6.235592e-004
2.760000e+000	6.237264e-004
2.770000e+000	6.238934e-004
2.780000e+000	6.240603e-004
2.790000e+000	6.242270e-004
2.800000e+000	6.243935e-004
2.810000e+000	6.245598e-004
2.820000e+000	6.247260e-004
2.830000e+000	6.248920e-004
2.840000e+000	6.250579e-004
2.850000e+000	6.252236e-004
2.860000e+000	6.253891e-004
2.870000e+000	6.255545e-004
2.880000e+000	6.257197e-004
2.890000e+000	6.258848e-004
2.900000e+000	6.260497e-004
2.910000e+000	6.262145e-004
2.920000e+000	6.263791e-004
2.930000e+000	6.265435e-004
2.940000e+000	6.267078e-004
2.950000e+000	6.268719e-004
2.960000e+000	6.270359e-004
2.970000e+000	6.271997e-004
2.980000e+000	6.273634e-004
2.990000e+000	6.275270e-004
3.000000e+000	6.276903e-004
3.010000e+000	6.278536e-004
3.020000e+000	6.280167e-004
3.030000e+000	6.281796e-004
3.040000e+000	6.283424e-004
3.050000e+000	6.285051e-004
3.060000e+000	6.286676e-004
3.070000e+000	6.288300e-004

VCE (V)	IC (A)
3.080000e+000	6.289922e-004
3.090000e+000	6.291543e-004
3.100000e+000	6.293162e-004
3.110000e+000	6.294780e-004
3.120000e+000	6.296397e-004
3.130000e+000	6.298012e-004
3.140000e+000	6.299626e-004
3.150000e+000	6.301239e-004
3.160000e+000	6.302850e-004
3.170000e+000	6.304460e-004
3.180000e+000	6.306069e-004
3.190000e+000	6.307676e-004
3.200000e+000	6.309282e-004
3.210000e+000	6.310886e-004
3.220000e+000	6.312489e-004
3.230000e+000	6.314091e-004
3.240000e+000	6.315692e-004
3.250000e+000	6.317291e-004
3.260000e+000	6.318889e-004
3.270000e+000	6.320486e-004
3.280000e+000	6.322082e-004
3.290000e+000	6.323676e-004
3.300000e+000	6.325269e-004
3.310000e+000	6.326861e-004
3.320000e+000	6.328451e-004
3.330000e+000	6.330040e-004
3.340000e+000	6.331628e-004
3.350000e+000	6.333215e-004
3.360000e+000	6.334801e-004
3.370000e+000	6.336385e-004
3.380000e+000	6.337968e-004
3.390000e+000	6.339550e-004
3.400000e+000	6.341131e-004
3.410000e+000	6.342710e-004
3.420000e+000	6.344289e-004
3.430000e+000	6.345866e-004
3.440000e+000	6.347442e-004
3.450000e+000	6.349017e-004
3.460000e+000	6.350590e-004
3.470000e+000	6.352163e-004
3.480000e+000	6.353734e-004
3.490000e+000	6.355305e-004
3.500000e+000	6.356874e-004
3.510000e+000	6.358442e-004
3.520000e+000	6.360008e-004
3.530000e+000	6.361574e-004
3.540000e+000	6.363139e-004
3.550000e+000	6.364702e-004
3.560000e+000	6.366265e-004
3.570000e+000	6.367826e-004
3.580000e+000	6.369386e-004

VCE (V)	IC (A)
3.590000e+000	6.370945e-004
3.600000e+000	6.372503e-004
3.610000e+000	6.374060e-004
3.620000e+000	6.375616e-004
3.630000e+000	6.377171e-004
3.640000e+000	6.378724e-004
3.650000e+000	6.380277e-004
3.660000e+000	6.381829e-004
3.670000e+000	6.383379e-004
3.680000e+000	6.384929e-004
3.690000e+000	6.386477e-004
3.700000e+000	6.388025e-004
3.710000e+000	6.389571e-004
3.720000e+000	6.391117e-004
3.730000e+000	6.392661e-004
3.740000e+000	6.394204e-004
3.750000e+000	6.395747e-004
3.760000e+000	6.397288e-004
3.770000e+000	6.398828e-004
3.780000e+000	6.400368e-004
3.790000e+000	6.401906e-004
3.800000e+000	6.403444e-004
3.810000e+000	6.404980e-004
3.820000e+000	6.406515e-004
3.830000e+000	6.408050e-004
3.840000e+000	6.409583e-004
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3.860000e+000	6.412648e-004
3.870000e+000	6.414178e-004
3.880000e+000	6.415708e-004
3.890000e+000	6.417237e-004
3.900000e+000	6.418764e-004
3.910000e+000	6.420291e-004
3.920000e+000	6.421817e-004
3.930000e+000	6.423342e-004
3.940000e+000	6.424866e-004
3.950000e+000	6.426389e-004
3.960000e+000	6.427912e-004
3.970000e+000	6.429433e-004
3.980000e+000	6.430954e-004
3.990000e+000	6.432473e-004
4.000000e+000	6.433992e-004
4.010000e+000	6.435509e-004
4.020000e+000	6.437026e-004
4.030000e+000	6.438542e-004
4.040000e+000	6.440057e-004
4.050000e+000	6.441572e-004
4.060000e+000	6.443085e-004
4.070000e+000	6.444597e-004
4.080000e+000	6.446109e-004
4.090000e+000	6.447620e-004

VCE (V)	IC (A)
4.100000e+000	6.449130e-004
4.110000e+000	6.450639e-004
4.120000e+000	6.452147e-004
4.130000e+000	6.453654e-004
4.140000e+000	6.455161e-004
4.150000e+000	6.456666e-004
4.160000e+000	6.458171e-004
4.170000e+000	6.459675e-004
4.180000e+000	6.461178e-004
4.190000e+000	6.462680e-004
4.200000e+000	6.464182e-004
4.210000e+000	6.465683e-004
4.220000e+000	6.467183e-004
4.230000e+000	6.468682e-004
4.240000e+000	6.470180e-004
4.250000e+000	6.471677e-004
4.260000e+000	6.473174e-004
4.270000e+000	6.474670e-004
4.280000e+000	6.476165e-004
4.290000e+000	6.477659e-004
4.300000e+000	6.479153e-004
4.310000e+000	6.480645e-004
4.320000e+000	6.482137e-004
4.330000e+000	6.483628e-004
4.340000e+000	6.485119e-004
4.350000e+000	6.486608e-004
4.360000e+000	6.488097e-004
4.370000e+000	6.489585e-004
4.380000e+000	6.491073e-004
4.390000e+000	6.492559e-004
4.400000e+000	6.494045e-004
4.410000e+000	6.495530e-004
4.420000e+000	6.497014e-004
4.430000e+000	6.498498e-004
4.440000e+000	6.499981e-004
4.450000e+000	6.501463e-004
4.460000e+000	6.502944e-004
4.470000e+000	6.504425e-004
4.480000e+000	6.505905e-004
4.490000e+000	6.507384e-004
4.500000e+000	6.508862e-004
4.510000e+000	6.510340e-004
4.520000e+000	6.511817e-004
4.530000e+000	6.513294e-004
4.540000e+000	6.514769e-004
4.550000e+000	6.516244e-004
4.560000e+000	6.517718e-004
4.570000e+000	6.519192e-004
4.580000e+000	6.520664e-004
4.590000e+000	6.522137e-004
4.600000e+000	6.523608e-004

4.610000e+000	6.525079e-004
4.620000e+000	6.526549e-004
4.630000e+000	6.528018e-004
4.640000e+000	6.529487e-004
4.650000e+000	6.530955e-004
4.660000e+000	6.532422e-004
4.670000e+000	6.533889e-004
4.680000e+000	6.535355e-004
4.690000e+000	6.536820e-004
4.700000e+000	6.538285e-004
4.710000e+000	6.539749e-004
4.720000e+000	6.541212e-004
4.730000e+000	6.542675e-004
4.740000e+000	6.544137e-004
4.750000e+000	6.545598e-004
4.760000e+000	6.547059e-004
4.770000e+000	6.548519e-004
4.780000e+000	6.549978e-004
4.790000e+000	6.551437e-004
4.800000e+000	6.552895e-004
4.810000e+000	6.554353e-004
4.820000e+000	6.555810e-004
4.830000e+000	6.557266e-004
4.840000e+000	6.558721e-004

VCE (V)	IC (A)
4.850000e+000	6.560176e-004
4.860000e+000	6.561631e-004
4.870000e+000	6.563085e-004
4.880000e+000	6.564538e-004
4.890000e+000	6.565990e-004
4.900000e+000	6.567442e-004
4.910000e+000	6.568893e-004
4.920000e+000	6.570344e-004
4.930000e+000	6.571794e-004
4.940000e+000	6.573244e-004
4.950000e+000	6.574693e-004
4.960000e+000	6.576141e-004
4.970000e+000	6.577589e-004
4.980000e+000	6.579036e-004
4.990000e+000	6.580482e-004
5.000000e+000	6.581928e-004
5.010000e+000	6.583374e-004
5.020000e+000	6.584818e-004
5.030000e+000	6.586263e-004
5.040000e+000	6.587706e-004
5.050000e+000	6.589149e-004
5.060000e+000	6.590592e-004
5.070000e+000	6.592034e-004
5.080000e+000	6.593475e-004
5.090000e+000	6.594916e-004
5.100000e+000	6.596356e-004

VCE (V)	IC (A)
5.110000e+000	6.597795e-004
5.120000e+000	6.599235e-004
5.130000e+000	6.600673e-004
5.140000e+000	6.602111e-004
5.150000e+000	6.603548e-004
5.160000e+000	6.604985e-004
5.170000e+000	6.606422e-004
5.180000e+000	6.607857e-004