

# McKelvey School of Engineering

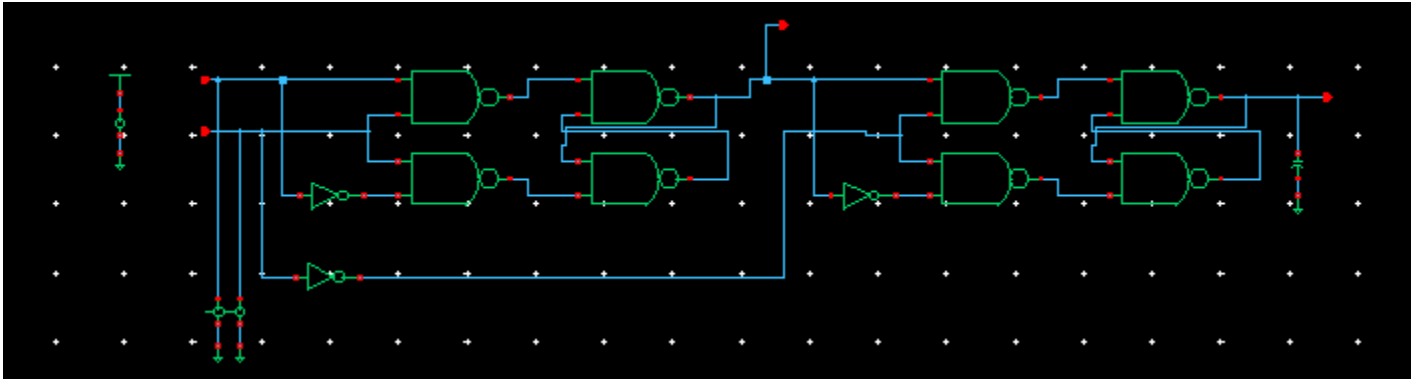
**Spring Semester 2023**

**CSE463M: Digital Integrated Circuit Design and Architecture**

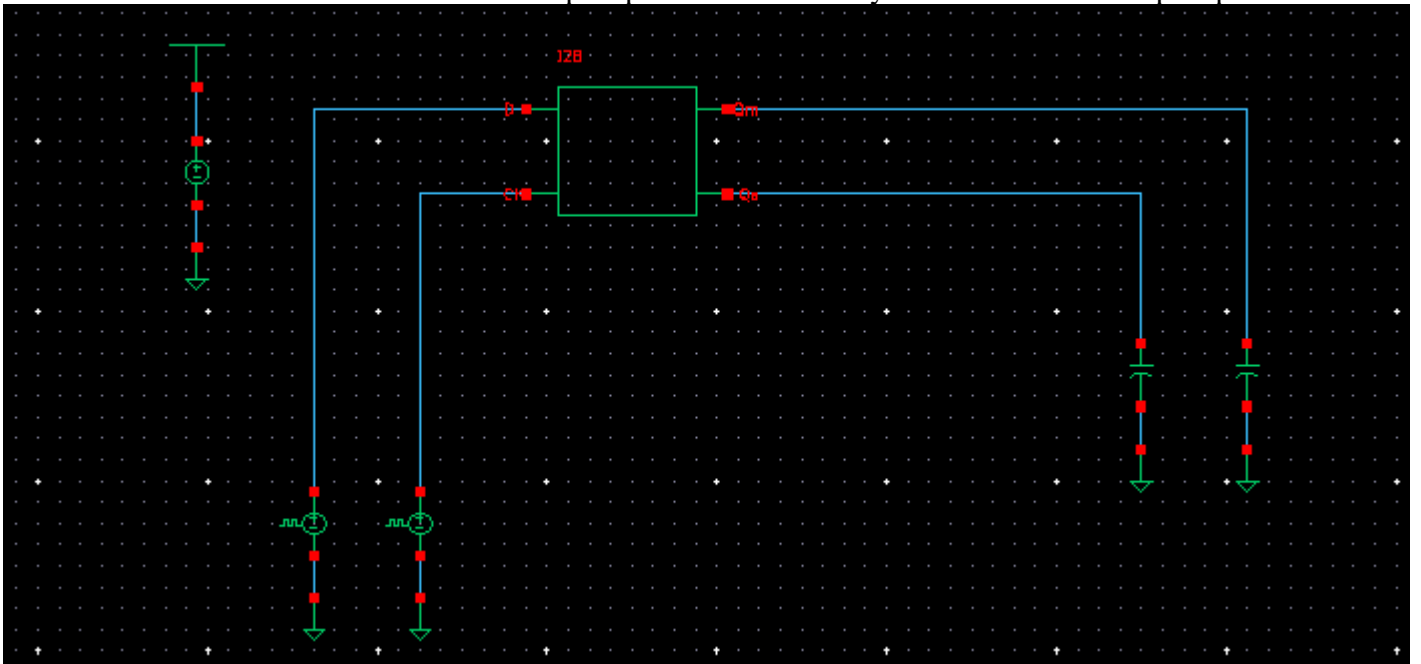
## **Homework #6**

- 1. Design a Master-Slave positive-edge clock triggered D Flip Flop.**
  - a. Draw the Master-Slave positive-edge clock triggered D Flip Flop schematic in Cadence and print it.**
  - b. Create an entire circuit schematic symbol and simulate the transient behavior of the circuit schematic with 100fF load on the output. Print the transient behavior. Transient behavior should show the entire truth table of the Master-Slave positive-edge clock triggered D Flip Flop.**
  - c. Draw the layout of the circuit. Perform DRC and LVS on the layout. Print the layout of the circuit, the DRC and the LVS messages.**
  - d. Simulate the transient behavior of the circuit layout with 100fF load on the output. Print the transient behavior. Transient behavior should show the entire truth table of the Master-Slave positive-edge clock triggered D Flip Flop. Also the transient behavior of the circuit schematic and the circuit layout should reasonably match.**

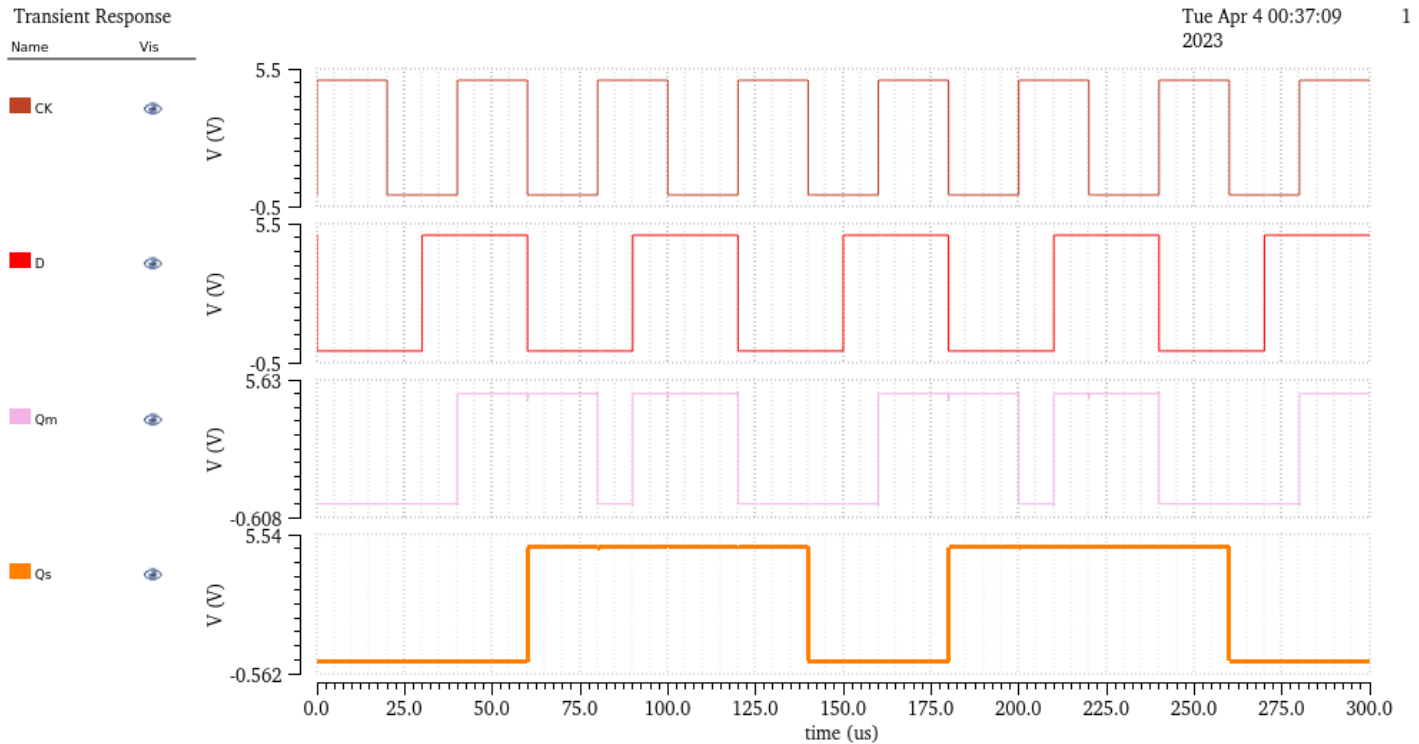
1.a. + Here is the schematic for the Master-Slave positive-edge D flip flop.



1.b + Here is the schematic for the MS D flip flop. We can see the symbol of the MS D flip flop.



+ Here is the schematic test result for the MS D flip flop. We can see that Qm get the part of the D input when CK clock is going up and hold that value. Also we can see that Qs get the part of the Qm when CK clock is going down and hold that value.

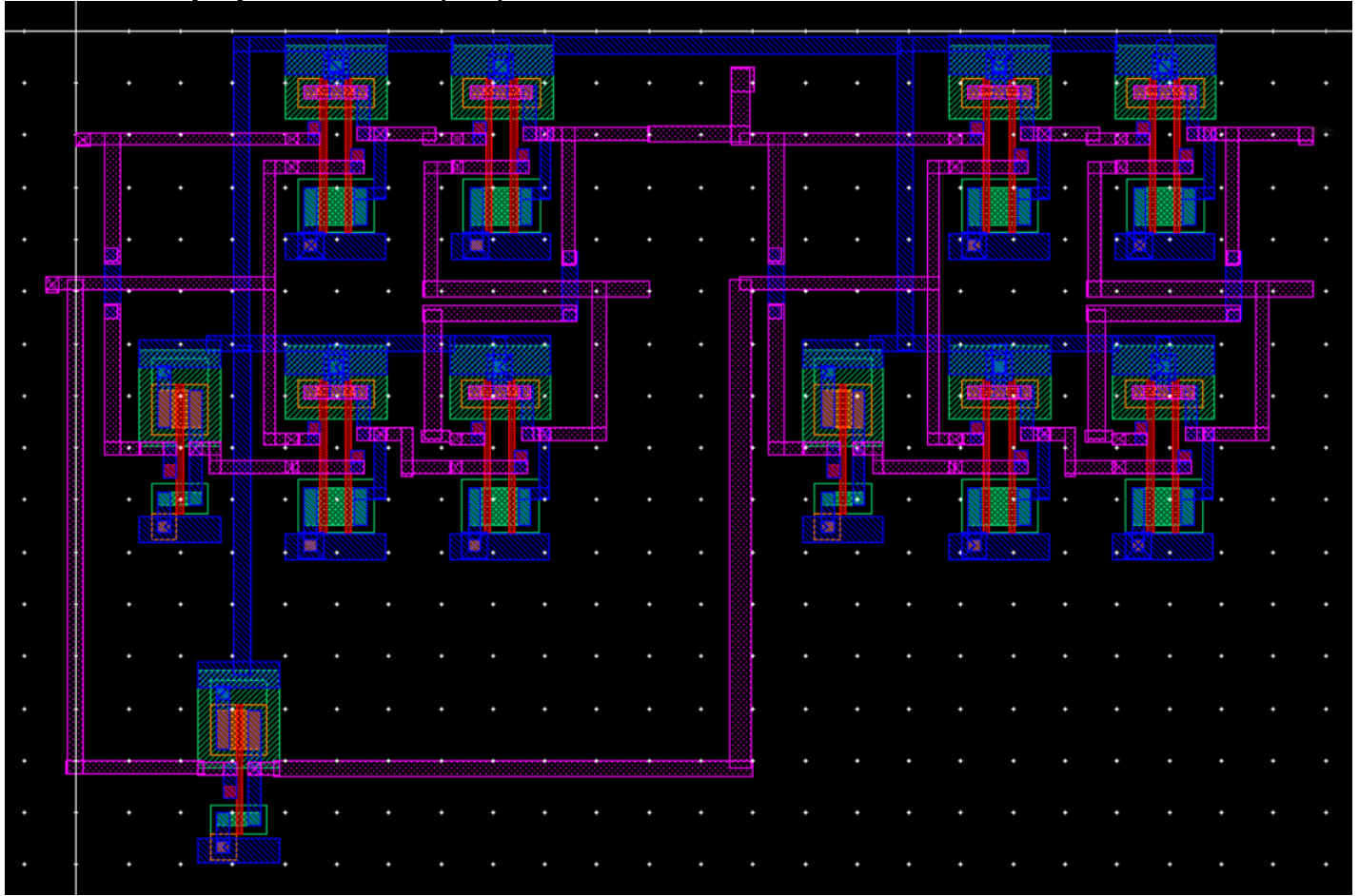


## Master Slave D flip flop Truth Table

D	Q(PREVIOUS)	CLOCK	Q
0	0	1	0
0	1	1	0
1	0	1	1
1	1	1	1
0	0	0	0
0	1	0	1
1	0	0	0
1	1	0	1

Table: Master slave D flip-flop Truth Table with input and output value.

1.c + Here is my layout of MS D flip flop.



+ Here is the result of DRC.

DRC started at Tue Apr 4 00:44:53 2023

Validating hierarchy instantiation for:

library: cse463

cell: inv\_homework63\_msff

view: layout

Rules come from library NCSU\_TechLib\_ami06.

Rules path is divaDRC.rul.

Inclusion limit is set to 1000.

Running layout DRC analysis

Flat mode

Full checking.

executing: nodrc = geomOr("nodrc")

executing: gwell = geomOr(geomAndNot(("gwell" "drawing") nodrc))

executing: nwell = geomOr(geomAndNot(("nwell" "drawing") nodrc))

executing: pwell = geomOr(geomAndNot(("pwell" "drawing") nodrc))

executing: nactive = geomOr(geomAndNot(("nactive" "drawing") nodrc))

executing: pactive = geomOr(geomAndNot(("pactive" "drawing") nodrc))

executing: active = geomOr(geomAndNot(("active" "drawing") nodrc) nactive pactive)

executing: gselect = geomOr(geomAndNot(("gselect" "drawing") nodrc))

executing: nselect = geomOr(geomAndNot(("nselect" "drawing") nodrc))

executing: pselect = geomOr(geomAndNot(("pselect" "drawing") nodrc))

executing: poly = geomOr(geomAndNot(("poly" "drawing") nodrc))

executing: metal1 = geomOr(geomAndNot(("metal1" "drawing") nodrc))

executing: cc = geomOr(geomAndNot(("cc" "drawing") nodrc))

executing: metal2 = geomOr(geomAndNot(("metal2" "drawing") nodrc))

executing: via = geomOr(geomAndNot(("via" "drawing") nodrc))

executing: glass = geomOr(geomAndNot(("glass" "drawing") nodrc))

executing: pad = geomOr(geomAndNot(("pad" "drawing") nodrc))

executing: res\_id = geomOr("res\_id")

executing: metal3 = geomOr(geomAndNot(("metal3" "drawing") nodrc))

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executing: via2 = geomOr(geomAndNot(("via2" "drawing") nodrc))
executing: highres = geomOr(geomAndNot(("highres" "drawing") nodrc))
executing: elec = geomOr(geomAndNot(("elec" "drawing") nodrc))
executing: ce = geomOr(geomOr(geomAndNot(("ce" "drawing") nodrc)) geomAnd(cc elec))
executing: cp = geomOr(geomOr(geomAndNot(("cp" "drawing") nodrc)) geomAnd(cc geomAndNot(poly ce)))
executing: ca = geomOr(geomOr(geomAndNot(("ca" "drawing") nodrc)) geomAnd(cc geomAndNot(active ...
executing: nActive = geomAnd(active nselect)
executing: pActive = geomAnd(active pselect)
executing: nBulk = geomOr(nwell)
executing: pBulk = geomOr(geomNot(nwell) geomAndNot(pwell nwell))
executing: nOhmic = geomAnd(nActive nwell)
        nNotOhmic = geomAndNot(nActive nwell)
executing: pOhmic = geomAndNot(pActive nwell)
        pNotOhmic = geomAnd(pActive nwell)
executing: nDiff = geomAndNot(nNotOhmic geomOr(poly elec))
executing: pDiff = geomAndNot(pNotOhmic geomOr(poly elec))
executing: nDiffContact = geomAnd(ca nDiff)
executing: pDiffContact = geomAnd(ca pDiff)
executing: nOhmicContact = geomAnd(ca nOhmic)
executing: pOhmicContact = geomAnd(ca pOhmic)
executing: Gate = geomAnd(geomOr(nNotOhmic pNotOhmic) poly)
executing: fieldPoly = geomAvoiding(poly Gate)
executing: elecGate = geomAnd(geomOr(nNotOhmic pNotOhmic) elec)
executing: fieldElec = geomAvoiding(elec elecGate)
executing: CapacitorElec = geomInside(elec poly)
executing: TransistorElec = geomOverlap(elec geomNot(poly))
executing: fieldPoly = geomAndNot(fieldPoly res_id)
executing: poly = geomAndNot(poly res_id)
executing: fieldElec = geomAndNot(fieldElec geomOr(res_id highres))
executing: elecRes = geomButting(geomAnd(res_id elec) fieldElec (keep == 2))
executing: elecHighres = geomButting(geomAnd(highres elec) fieldElec (keep == 2))
executing: elec = geomAndNot(elec geomOr(res_id highres))
executing: nBulk = geomAndNot(nBulk res_id)
executing: nwell = geomAndNot(nwell res_id)
executing: geomConnect((via nOhmicContact nOhmic nwell nBulk metal1) (via pOhmicContact pOhmic ...
executing: dubiousData(("gwell" "drawing") "Improperly formed shape - gwell")
executing: dubiousData(("nwell" "drawing") "Improperly formed shape - nwell")
executing: dubiousData(("pwell" "drawing") "Improperly formed shape - pwell")
executing: dubiousData(("active" "drawing") "Improperly formed shape - active, nactive or pactive...
executing: dubiousData(("gselect" "drawing") "Improperly formed shape - gselect")
executing: dubiousData(("nselect" "drawing") "Improperly formed shape - nselect")
executing: dubiousData(("pselect" "drawing") "Improperly formed shape - pselect")
executing: dubiousData(("poly" "drawing") "Improperly formed shape - poly")
executing: dubiousData(("metal1" "drawing") "Improperly formed shape - metal1")
executing: dubiousData(("ca" "drawing") "Improperly formed shape - ca")
executing: dubiousData(("cp" "drawing") "Improperly formed shape - cp")
executing: dubiousData(("metal2" "drawing") "Improperly formed shape - metal2")
executing: dubiousData(("via" "drawing") "Improperly formed shape - via")
executing: dubiousData(("glass" "drawing") "Improperly formed shape - glass")
executing: saveDerived(geomGetNon45(gwell) "Non-Manhattan shape - gwell")
executing: saveDerived(geomGetNon45(nwell) "Non-Manhattan shape - nwell")
executing: saveDerived(geomGetNon45(pwell) "Non-Manhattan shape - pwell")
executing: saveDerived(geomGetNon45(active) "Non-Manhattan shape - active, nactive or pactive")
executing: saveDerived(geomGetNon45(gselect) "Non-Manhattan shape - gselect")
executing: saveDerived(geomGetNon45(nselect) "Non-Manhattan shape - nselect")
executing: saveDerived(geomGetNon45(pselect) "Non-Manhattan shape - pselect")
executing: saveDerived(geomGetNon45(poly) "Non-Manhattan shape - poly")
executing: saveDerived(geomGetNon45(metal1) "Non-Manhattan shape - metal1")
executing: saveDerived(geomGetNon45(ca) "Non-Manhattan shape - ca")
executing: saveDerived(geomGetNon45(cp) "Non-Manhattan shape - cp")
executing: saveDerived(geomGetNon45(metal2) "Non-Manhattan shape - metal2")
executing: saveDerived(geomGetNon45(via) "Non-Manhattan shape - via")
executing: saveDerived(geomGetNon45(glass) "Non-Manhattan shape - glass")
executing: offGrid(gwell gridRes "(SCMOS Inst) Edge not on grid")
executing: offGrid(nwell gridRes "(SCMOS Inst) Edge not on grid")
executing: offGrid(pwell gridRes "(SCMOS Inst) Edge not on grid")
executing: offGrid(active gridRes "(SCMOS Inst) Edge not on grid")
executing: offGrid(gselect gridRes "(SCMOS Inst) Edge not on grid")
executing: offGrid(nselect gridRes "(SCMOS Inst) Edge not on grid")

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executing: offGrid(pselect gridRes "(SCMOS Inst) Edge not on grid")
executing: offGrid(poly gridRes "(SCMOS Inst) Edge not on grid")
executing: offGrid(metal1 gridRes "(SCMOS Inst) Edge not on grid")
executing: offGrid(ca gridRes "(SCMOS Inst) Edge not on grid")
executing: offGrid(cp gridRes "(SCMOS Inst) Edge not on grid")
executing: offGrid(metal2 gridRes "(SCMOS Inst) Edge not on grid")
executing: offGrid(via gridRes "(SCMOS Inst) Edge not on grid")
executing: offGrid(glass gridRes "(SCMOS Inst) Edge not on grid")
executing: dubiousData(("metal3" "drawing") "Improperly formed shape - metal3")
executing: dubiousData(("via2" "drawing") "Improperly formed shape - via2")
executing: saveDerived(geomGetNon45(metal3) "Non-Manhattan shape - metal3")
executing: saveDerived(geomGetNon45(via2) "Non-Manhattan shape - via2")
executing: offGrid(metal3 gridRes "(SCMOS Inst) Edge not on grid")
executing: offGrid(via2 gridRes "(SCMOS Inst) Edge not on grid")
executing: dubiousData(("elec" "drawing") "Improperly formed shape - elec")
executing: dubiousData(("ce" "drawing") "Improperly formed shape - ce")
executing: saveDerived(geomGetNon45(elec) "Non-Manhattan shape - elec")
executing: saveDerived(geomGetNon45(ce) "Non-Manhattan shape - ce")
executing: offGrid(elec gridRes "(SCMOS Inst) Edge not on grid")
executing: offGrid(ce gridRes "(SCMOS Inst) Edge not on grid")
executing: nwellEdge = geomGetEdge(nwell)
executing: pwellEdge = geomGetEdge(pwell)
executing: activeEdge = geomGetEdge(active)
executing: nselectEdge = geomGetEdge(nselect)
executing: pselectEdge = geomGetEdge(pselect)
executing: polyEdge = geomGetEdge(poly)
executing: metal1Edge = geomGetEdge(metal1)
executing: caEdge = geomGetEdge(ca)
executing: cpEdge = geomGetEdge(cp)
executing: metal2Edge = geomGetEdge(metal2)
executing: viaEdge = geomGetEdge(via)
executing: glassEdge = geomGetEdge(glass)
executing: highresEdge = geomGetEdge(highres)
executing: ceEdge = geomGetEdge(ce)
executing: metal3Edge = geomGetEdge(metal3)
executing: via2Edge = geomGetEdge(via2)
executing: nBulkEdge = geomGetEdge(nBulk)
executing: pBulkEdge = geomGetEdge(pBulk)
executing: nOhmicEdge = geomGetEdge(nOhmic)
executing: pOhmicEdge = geomGetEdge(pOhmic)
executing: nNotOhmicEdge = geomGetEdge(nNotOhmic)
executing: pNotOhmicEdge = geomGetEdge(pNotOhmic)
executing: GateEdge = geomGetEdge(Gate)
executing: fieldPolyEdge = geomGetEdge(fieldPoly)
executing: CapacitorElecEdge = geomGetEdge(CapacitorElec)
executing: TransistorElecEdge = geomGetEdge(TransistorElec)
executing: elecHighresEdge = geomGetEdge(elecRes coincident elec)
executing: saveDerived(geomAndNot(active geomOr(nselect pselect)) "(DBM Rule 1.1) Active must b...
executing: saveDerived(geomAnd(poly nOhmic) "(DBM Rule 2.0) Poly cannot overlap ohmic diffusion")
executing: saveDerived(geomAnd(poly pOhmic) "(DBM Rule 2.0) Poly cannot overlap ohmic diffusion")
executing: saveDerived(geomAnd(elec nOhmic) "(DBM Rule 2.1) Elec cannot overlap ohmic diffusion")
executing: saveDerived(geomAnd(elec pOhmic) "(DBM Rule 2.1) Elec cannot overlap ohmic diffusion")
executing: saveDerived(geomAnd(pactive nselect) "(DBM Rule 3.1) Pactive and Nselect may not ove...
executing: saveDerived(geomAnd(nactive pselect) "(DBM Rule 3.2) Nactive and Pselect may not ove...
executing: saveDerived(geomAnd(active elec) "(DBM Rule 4.0, AMI 0.6um) Elec and active may not ...
executing: drc(nwellEdge (width < (lambda * 12.0)) errMesg)
    drc(nwellEdge (notch < (lambda * 6.0)) errMesg)
executing: drc(pwellEdge (width < (lambda * 12.0)) errMesg)
    drc(pwellEdge (notch < (lambda * 6.0)) errMesg)
executing: drc(nwell (sep < (lambda * 18.0)) diffNet errMesg)
    drc(nwell (sep < (lambda * 6.0)) sameNet errMesg)
executing: drc(pwell (sep < (lambda * 18.0)) diffNet errMesg)
    drc(pwell (sep < (lambda * 6.0)) sameNet errMesg)
executing: saveDerived(geomAnd(nwell pwell) "(SCMOS Rule 1 note) n-wells and p-wells may not ov...
executing: drc(activeEdge (width < (lambda * 3.0)) errMesg)
    drc(activeEdge (sep < (lambda * 3.0)) errMesg)
    drc(activeEdge (notch < (lambda * 3.0)) errMesg)
executing: drc(nNotOhmicEdge nBulkEdge (sep < (lambda * 6.0)) errMesg)
executing: drc(pNotOhmicEdge pBulkEdge (sep < (lambda * 6.0)) errMesg)

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executing: drc(pBulkEdge nNotOhmicEdge (enc < (lambda * 6.0)) errMesg)
executing: drc(nBulkEdge pNotOhmicEdge (enc < (lambda * 6.0)) errMesg)
executing: drc(nBulkEdge nOhmicEdge (enc < (lambda * 3.0)) errMesg)
executing: drc(nOhmicEdge pBulkEdge (sep < (lambda * 3.0)) errMesg)
executing: drc(pOhmicEdge nBulkEdge (sep < (lambda * 3.0)) errMesg)
executing: drc(pBulkEdge pOhmicEdge (enc < (lambda * 3.0)) errMesg)
executing: drc(nNotOhmicEdge pOhmicEdge ((0 < sep) < (lambda * 4.0)) errMesg)
executing: drc(pNotOhmicEdge nOhmicEdge ((0 < sep) < (lambda * 4.0)) errMesg)
executing: drc(polyEdge (width < (lambda * 2.0)) errMesg)
    drc(polyEdge (sep < (lambda * 3.0)) errMesg)
    drc(polyEdge (notch < (lambda * 3.0)) errMesg)
executing: drc(polyEdge activeEdge (enc < (lambda * 2.0)) errMesg)
    drc(activeEdge polyEdge (enc < (lambda * 3.0)) errMesg)
    drc(polyEdge activeEdge (sep < (lambda * 1.0)) errMesg)
executing: drc(nselectEdge geomGetEdge(polyEdge inside pNotOhmic) (sep < (lambda * 3.0)) (app >...
executing: drc(nselectEdge geomGetEdge(polyEdge inside nNotOhmic) (enc < (lambda * 3.0)) (app >...
executing: drc(pselectEdge geomGetEdge(polyEdge inside nNotOhmic) (sep < (lambda * 3.0)) (app >...
executing: drc(pselectEdge geomGetEdge(polyEdge inside pNotOhmic) (enc < (lambda * 3.0)) (app >...
executing: drc(geomOr(nselectEdge pselectEdge) activeEdge (sep < (lambda * 2.0)) errMesg)
    drc(geomOr(nselectEdge pselectEdge) activeEdge (enc < (lambda * 2.0)) errMesg)
executing: drc(nselectEdge caEdge (sep < (lambda * 1.0)) errMesg)
    drc(nselectEdge caEdge (enc < (lambda * 1.0)) errMesg)
executing: drc(pselectEdge caEdge (sep < (lambda * 1.0)) errMesg)
    drc(pselectEdge caEdge (enc < (lambda * 1.0)) errMesg)
executing: saveDerived(geomButting(geomAnd(ca nselect) geomAnd(ca pselect)) errMesg)
executing: drc(nselectEdge (width < (lambda * 2.0)) errMesg)
    drc(nselectEdge (sep < (lambda * 2.0)) errMesg)
    drc(nselectEdge (notch < (lambda * 2.0)) errMesg)
executing: drc(pselectEdge (width < (lambda * 2.0)) errMesg)
    drc(pselectEdge (sep < (lambda * 2.0)) errMesg)
    drc(pselectEdge (notch < (lambda * 2.0)) errMesg)
executing: saveDerived(geomAnd(nselect pselect) errMesg)
executing: drc(cpEdge (width < (lambda * 2.0)) errMesg)
    drc(cpEdge (sep < (lambda * 3.0)) errMesg)
    drc(cpEdge (notch < (lambda * 3.0)) errMesg)
executing: drc(cp (area > ((lambda * 2.0 * (lambda * 2.0)) + (lambda * 0.1 * (lambda * 0.1)))) ...
executing: drc(polyEdge cpEdge (enc < (lambda * 1.0)) errMesg)
    drc(cpEdge polyEdge (sep < (lambda * 5.0)) errMesg)
executing: saveDerived(geomAndNot(cp poly) errMesg)
executing: saveDerived(geomAndNot(cc geomOr(poly elec active)) errMesg)
executing: drc(cpEdge GateEdge (sep < (lambda * 2.0)) errMesg)
executing: drc(cpEdge activeEdge (sep < (lambda * 2.0)) errMesg)
executing: saveDerived(geomAnd(cp active) errMesg)
executing: saveDerived(geomGetLength(drc(cpEdge activeEdge (sep < (lambda * 3.0))) (length > (l...
executing: drc(caEdge (width < (lambda * 2.0)) errMesg)
    drc(caEdge (sep < (lambda * 3.0)) errMesg)
    drc(caEdge (notch < (lambda * 3.0)) errMesg)
executing: drc(ca (area > ((lambda * 2.0 * (lambda * 2.0)) + (lambda * 0.1 * (lambda * 0.1)))) ...
executing: drc(activeEdge caEdge (enc < (lambda * 1.0)) errMesg)
    drc(caEdge activeEdge (sep < (lambda * 5.0)) errMesg)
executing: saveDerived(geomAndNot(ca active) errMesg)
executing: drc(caEdge GateEdge (sep < (lambda * 2.0)) errMesg)
executing: saveDerived(geomAnd(ca Gate) errMesg)
executing: drc(caEdge fieldPolyEdge (sep < (lambda * 2.0)) errMesg)
executing: saveDerived(geomAnd(ca fieldPoly) errMesg)
executing: saveDerived(geomGetLength(drc(caEdge fieldPolyEdge (sep < (lambda * 3.0))) (length >...
executing: drc(caEdge cpEdge (sep < (lambda * 4.0)) errMesg)
executing: saveDerived(geomAnd(ca cp) errMesg)
executing: drc(metal1Edge (width < (lambda * 3.0)) errMesg)
    drc(metal1Edge (sep < (lambda * 3.0)) errMesg)
    drc(metal1Edge (notch < (lambda * 3.0)) errMesg)
executing: drc(metal1Edge cpEdge (enc < (lambda * 1.0)) errMesg)
executing: drc(metal1Edge caEdge (enc < (lambda * 1.0)) errMesg)
executing: saveDerived(geomAndNot(cp metal1) errMesg)
executing: saveDerived(geomAndNot(ca metal1) errMesg)
executing: drc(viaEdge (width < (lambda * 2.0)) errMesg)
    drc(viaEdge (sep < (lambda * 3.0)) errMesg)
executing: drc(via (area > ((lambda * 2.0 * (lambda * 2.0)) + (lambda * 0.1 * (lambda * 0.1))))...
executing: drc(metal1Edge viaEdge (enc < (lambda * 1.0)) errMesg)

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executing: saveDerived(geomAndNot(via metal1) errMesg)
executing: drc(metal2Edge (width < (lambda * 3.0)) errMesg)
    drc(metal2Edge (sep < (lambda * 3.0)) errMesg)
    drc(metal2Edge (notch < (lambda * 3.0)) errMesg)
executing: drc(metal2Edge viaEdge (enc < (lambda * 1.0)) errMesg)
executing: saveDerived(geomAndNot(via metal2) errMesg)
executing: BondingGlass = geomInside(glass pad)
    ProbeGlass = geomOutside(glass pad)
executing: saveDerived(geomStraddle(glass pad))
executing: BondingPad = geomAndNot(geomSize(BondingGlass 6.0) geomHoles(BondingGlass))
executing: ProbePad = geomAndNot(geomSize(ProbeGlass 6.0) geomHoles(ProbeGlass))
executing: Pad = geomOr(BondingPad ProbePad)
executing: BondingPadEdge = geomGetEdge(BondingPad not_over "nodrc")
executing: ProbePadEdge = geomGetEdge(ProbePad not_over "nodrc")
executing: PadEdge = geomGetEdge(Pad not_over "nodrc")
executing: Metal3EdgeNearPad = geomGetEdge(geomOr(geomGetByLayer("metal3" "glass" 36.0)) not_ov...
executing: Metal2EdgeNearPad = geomGetEdge(geomOr(geomGetByLayer("metal2" "glass" 36.0)) not_ov...
executing: Metal1EdgeNearPad = geomGetEdge(geomOr(geomGetByLayer("metal1" "glass" 21.0)) not_ov...
executing: PolyEdgeNearPad = geomGetEdge(geomOr(geomGetByLayer("poly" "glass" 21.0)) not_over "...
executing: ActiveEdgeNearPad = geomGetEdge(geomOr(geomGetByLayer("active" "glass" 21.0)) not_ov...
executing: ElecEdgeNearPad = geomGetEdge(geomOr(geomGetByLayer("elec" "glass" 21.0)) not_over "...
executing: drc(BondingPadEdge (width < 60.0) "(SCMOS Rule 10.1) bonding pad width: 60 um")
executing: drc(ProbePadEdge (width < 20.0) "(SCMOS Rule 10.2) probe pad width: 20 um")
executing: drc(Metal3EdgeNearPad glassEdge (enc < 6.0) "(SCMOS Rule 10.3) pad enclosure of glas...
executing: saveDerived(geomAndNot(glass metal3) "(SCMOS Rule 10.3) pad enclosure of glass: 6 um")
executing: drc(PadEdge Metal3EdgeNearPad (sep < 30.0) "(SCMOS Rule 10.4) pad to unrelated metal...
executing: drc(PadEdge Metal2EdgeNearPad (sep < 30.0) "(SCMOS Rule 10.4) pad to unrelated metal...
executing: drc(PadEdge Metal1EdgeNearPad (sep < 15.0) "(SCMOS Rule 10.5) pad to unrelated metal...
executing: drc(PadEdge PolyEdgeNearPad (sep < 15.0) "(SCMOS Rule 10.5) pad to unrelated poly sp...
executing: drc(PadEdge ActiveEdgeNearPad (sep < 15.0) "(SCMOS Rule 10.5) pad to unrelated activ...
executing: drc(PadEdge ElecEdgeNearPad (sep < 15.0) "(SCMOS Rule 10.5) pad to unrelated elec sp...
executing: drc(CapacitorElecEdge (width < (lambda * 7.0)) errMesg)
    drc(CapacitorElecEdge (sep < (lambda * 3.0)) errMesg)
    drc(CapacitorElecEdge (notch < (lambda * 3.0)) errMesg)
executing: drc(polyEdge CapacitorElecEdge (enc < (lambda * 5.0)) errMesg)
executing: drc(CapacitorElecEdge nBulkEdge (sep < (lambda * 2.0)) errMesg)
    drc(nBulkEdge CapacitorElecEdge (enc < (lambda * 2.0)) errMesg)
executing: drc(CapacitorElecEdge pBulkEdge (sep < (lambda * 2.0)) errMesg)
    drc(pBulkEdge CapacitorElecEdge (enc < (lambda * 2.0)) errMesg)
executing: saveDerived(geomStraddle(CapacitorElec nBulk) errMesg)
executing: saveDerived(geomStraddle(CapacitorElec pBulk) errMesg)
executing: drc(CapacitorElecEdge activeEdge (sep < (lambda * 2.0)) errMesg)
executing: saveDerived(geomAnd(CapacitorElec active) errMesg)
executing: drc(CapacitorElecEdge cpEdge (sep < (lambda * 6.0)) errMesg)
executing: drc(geomGetEdge("elec") geomGetEdge("metal3") (sep < (lambda * 2.0)) errMesg)
executing: saveDerived(geomOverlap(metal3 elec diffNet) errMesg)
executing: drc(geomGetEdge("elec") geomGetEdge("metal2") (sep < (lambda * 2.0)) errMesg)
executing: saveDerived(geomOverlap(metal2 elec diffNet) errMesg)
executing: drc(geomGetEdge("elec") geomGetEdge("metal1") (sep < (lambda * 2.0)) errMesg)
executing: saveDerived(geomOverlap(metal1 elec diffNet) errMesg)
executing: drc(TransistorElecEdge (width < (lambda * 2.0)) errMesg)
    drc(TransistorElecEdge (sep < (lambda * 3.0)) errMesg)
    drc(TransistorElecEdge (notch < (lambda * 3.0)) errMesg)
executing: drc(TransistorElecEdge activeEdge (enc < (lambda * 2.0)) errMesg)
    drc(TransistorElecEdge activeEdge (sep < (lambda * 1.0)) errMesg)
executing: drc(TransistorElecEdge polyEdge (sep < (lambda * 2.0)) errMesg)
    drc(TransistorElecEdge polyEdge (ovlp < (lambda * 2.0)) errMesg)
executing: drc(TransistorElecEdge cpEdge (sep < (lambda * 3.0)) errMesg)
executing: saveDerived(geomAnd(TransistorElec cp) errMesg)
executing: drc(TransistorElecEdge caEdge (sep < (lambda * 3.0)) errMesg)
executing: saveDerived(geomAnd(TransistorElec ca) errMesg)
executing: drc(ceEdge (width < (lambda * 2.0)) errMesg)
    drc(ceEdge (sep < (lambda * 3.0)) errMesg)
    drc(ceEdge (notch < (lambda * 3.0)) errMesg)
executing: drc(ce (area > ((lambda * 2.0 * (lambda * 2.0)) + (lambda * 0.1 * (lambda * 0.1)))) ...
executing: drc(CapacitorElecEdge ceEdge (enc < (lambda * 3.0)) errMesg)
executing: drc(TransistorElecEdge ceEdge (enc < (lambda * 2.0)) errMesg)
executing: saveDerived(geomAndNot(ce elec) "(SCMOS Rules 13.3,13.4) electrode enclosure of cont...
executing: drc(ceEdge polyEdge (sep < (lambda * 3.0)) errMesg)

```



```

executing: saveDerived(geomOutside(geomAnd(ce poly) CapacitorElec) errMesg)
executing: drc(ceEdge activeEdge (sep < (lambda * 3.0)) errMesg)
executing: saveDerived(geomAnd(ce active) errMesg)
executing: drc(via2Edge (width < (lambda * 2.0)) errMesg)
    drc(via2Edge (sep < (lambda * 3.0)) errMesg)
executing: drc(via2 (area > ((lambda * 2.0 * (lambda * 2.0)) + (lambda * 0.1 * (lambda * 0.1)))...
executing: drc(metal2Edge via2Edge (enc < (lambda * 1.0)) errMesg)
executing: saveDerived(geomAndNot(via2 metal2) errMesg)
executing: drc(metal3Edge (width < (lambda * 5.0)) errMesg)
    drc(metal3Edge (sep < (lambda * 3.0)) errMesg)
    drc(metal3Edge (notch < (lambda * 3.0)) errMesg)
executing: drc(metal3Edge via2Edge (enc < (lambda * 2.0)) errMesg)
executing: saveDerived(geomAndNot(via2 metal3) errMesg)
executing: drc(highresEdge (width < (lambda * 4.0)) errMesg)
    drc(highresEdge (sep < (lambda * 4.0)) errMesg)
    drc(highresEdge (notch < (lambda * 4.0)) errMesg)
executing: drc(highresEdge caEdge (sep < (lambda * 2.0)) errMesg)
executing: drc(highresEdge cpEdge (sep < (lambda * 2.0)) errMesg)
executing: saveDerived(geomAnd(highres ca) errMesg)
executing: saveDerived(geomAnd(highres cp) errMesg)
executing: drc(highresEdge activeEdge (sep < (lambda * 2.0)) errMesg)
executing: drc(highresEdge geomGetEdge(geomAndNot(elec geomButting(elec elecHighres))) (sep < (...
executing: saveDerived(geomButting(elecHighres geomAndNot(elec elecHighres) (ignore == 2)) errM...
executing: saveDerived(geomAnd(elecHighres nwell) "(SCMOS Rule 27.6) resistor must be outside w...
executing: saveDerived(geomAnd(elecHighres active) "(SCMOS Rule 27.6) resistor must be outside ...
executing: drc(elecHighresEdge (width < (lambda * 5.0)) errMesg)
    drc(elecHighresEdge (sep < (lambda * 7.0)) errMesg)
    drc(elecHighresEdge (notch < (lambda * 7.0)) errMesg)
executing: drc(highresEdge elecHighresEdge (enc < (lambda * 2.0)) errMesg)
DRC started.....Tue Apr 4 00:44:53 2023
completed ....Tue Apr 4 00:44:53 2023
CPU TIME = 00:00:00 TOTAL TIME = 00:00:00
***** Summary of rule violations for cell "inv_homework63_msff layout" *****
Total errors found: 0

```

## + Here is the LVS result of the layout.

```
@(#)$CDS: LVS version 6.1.8-64b 08/09/2022 19:10 (sjfhw317) $
```

Command line: /project/engineering/cadence21/IC618/tools.lnx86/dfil/bin/64bit/LVS -dir /home/warehouse/b.gwak/cadence/LVS -l -s -t /home/warehouse/b.gwak/cadence/LVS/layout /home/warehouse/b.gwak/cadence/LVS/schematic

Like matching is enabled.

Net swapping is enabled.

Using terminal names as correspondence points.

Compiling Diva LVS rules...

Net-list summary for /home/warehouse/b.gwak/cadence/LVS/layout/netlist

```

count
23      nets
4        terminals
19      pmos
19      nmos

```

Net-list summary for /home/warehouse/b.gwak/cadence/LVS/schematic/netlist

```

count
23      nets
6        terminals
19      pmos
19      nmos

```

Terminal correspondence points

```

N20    N7    CK
N19    N11   D
N22    N15   Qm
N21    N16   Qs

```

Devices in the netlist but not in the rules:

pcapacitor

Devices in the rules but not in the netlist:

cap nfet pfet nmos4 pmos4

The net-lists match.

	layout	schematic
	instances	
un-matched	0	0
rewired	0	0
size errors	0	0
pruned	0	0
active	38	38
total	38	38

	nets	
un-matched	0	0
merged	0	0
pruned	0	0
active	23	23
total	23	23

	terminals	
un-matched	0	0
matched but different type	0	0
total	4	6

Probe files from /home/warehouse/b.gwak/cadence/LVS/schematic

devbad.out:

netbad.out:

mergenet.out:

termbad.out:

prunenet.out:

prunedev.out:

audit.out:

Probe files from /home/warehouse/b.gwak/cadence/LVS/layout

devbad.out:

netbad.out:

mergenet.out:

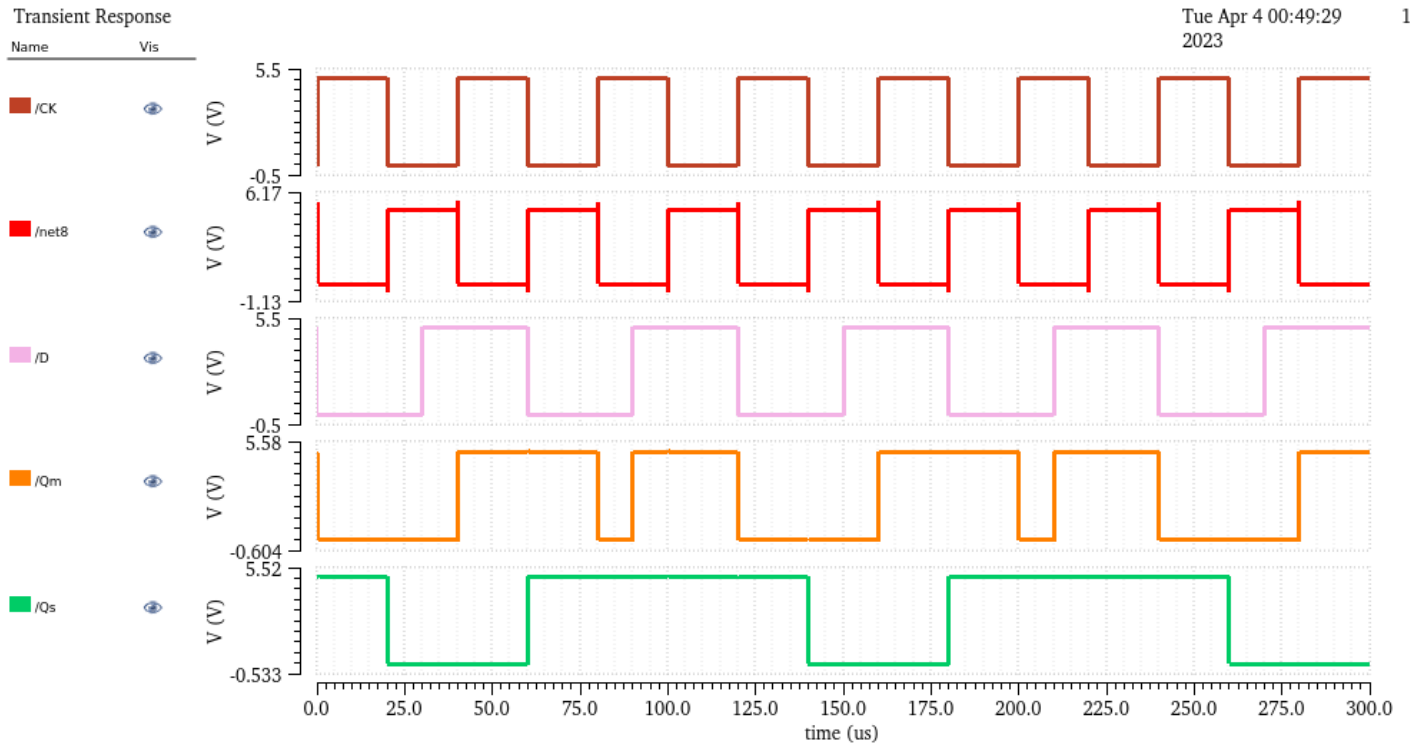
termbad.out:

prunenet.out:

prunedev.out:

audit.out:

1.d + Here is the layout result of the MS D flip flop. We can see that the result is the same with the schematic version.



+ Here is the proof that I tested on the extracted version.

```
// Generated for: spectre
// Generated on: Apr 4 00:48:57 2023
// Design library name: cse463
// Design cell name: inv_homework63_msff
// Design view name: schematic
simulator lang=spectre
global 0 vdd!
include "/project/linuxlab/cadence/CDK/ncsu/models/spectre/nom/ami06N.m"
include "/project/linuxlab/cadence/CDK/ncsu/models/spectre/nom/ami06P.m"

// Library name: cse463
// Cell name: inv_homework43_nand
// View name: extracted
// View type: maskLayout
subckt inv_homework43_nand_extracted A B OUT
  \+3 (OUT B vdd! vdd!) ami06P w=9e-07 l=6e-07 as=9.9e-13 ad=1.71e-12 \
    ps=2.1e-06 pd=4.5e-06 m=1 region=sat
  \+2 (vdd! A OUT vdd!) ami06P w=9e-07 l=6e-07 as=1.71e-12 ad=9.9e-13 \
    ps=4.5e-06 pd=2.1e-06 m=1 region=sat
  \+19 (B 0) capacitor c=5.4405e-16 m=1
  \+18 (A 0) capacitor c=5.4405e-16 m=1
  \+17 (vdd! B) capacitor c=1.5903e-16 m=1
  \+16 (vdd! A) capacitor c=1.5903e-16 m=1
  \+15 (OUT 0) capacitor c=2.04348e-15 m=1
  \+14 (B 0) capacitor c=2.9946e-16 m=1
  \+13 (A 0) capacitor c=2.9946e-16 m=1
  \+12 (vdd! 0) capacitor c=1.956e-15 m=1
  \+11 (vdd! OUT) capacitor c=6.054e-16 m=1
  \+10 (OUT 0) capacitor c=7.878e-17 m=1
  \+9 (B 0) capacitor c=6.9852e-16 m=1
  \+8 (B OUT) capacitor c=1.8504e-16 m=1
  \+7 (A 0) capacitor c=3.2292e-16 m=1
  \+6 (A OUT) capacitor c=1.8504e-16 m=1
  \+5 (A B) capacitor c=1.8504e-16 m=1
  \+4 (vdd! OUT) capacitor c=3.999e-16 m=1
```

```

\+1 (OUT B 6 0) ami06N w=3.6e-06 l=6e-07 as=3.24e-12 ad=5.4e-12 \
  ps=1.8e-06 pd=6.6e-06 m=1 region=sat
\+0 (6 A 0 0) ami06N w=3.6e-06 l=6e-07 as=5.4e-12 ad=3.24e-12 \
  ps=6.6e-06 pd=1.8e-06 m=1 region=sat
ends inv_homework43_nand_extracted
// End of subcircuit definition.

// Library name: cse463
// Cell name: inv_homework3_inv
// View name: extracted
// View type: maskLayout
subckt inv_homework3_inv_extracted in out
  \+1 (out in vdd! vdd!) ami06P w=3.6e-06 l=6e-07 as=6.48e-12 \
    ad=6.48e-12 ps=7.2e-06 pd=7.2e-06 m=1 region=sat
  \+12 (in 0) capacitor c=4.2687e-16 m=1
  \+11 (in vdd!) capacitor c=1.3392e-16 m=1
  \+10 (vdd! 0) capacitor c=1.59252e-15 m=1
  \+9 (out 0) capacitor c=9.5022e-16 m=1
  \+8 (out vdd!) capacitor c=4.4736e-16 m=1
  \+7 (in 0) capacitor c=4.4736e-16 m=1
  \+6 (in vdd!) capacitor c=2.7354e-16 m=1
  \+5 (out 0) capacitor c=2.4585e-16 m=1
  \+4 (out vdd!) capacitor c=2.1951e-16 m=1
  \+3 (in 0) capacitor c=3.153e-16 m=1
  \+2 (in vdd!) capacitor c=2.8518e-16 m=1
  \+0 (out in 0 0) ami06N w=1.2e-06 l=6e-07 as=2.16e-12 ad=2.16e-12 \
    ps=4.8e-06 pd=4.8e-06 m=1 region=sat
ends inv_homework3_inv_extracted
// End of subcircuit definition.

// Library name: cse463
// Cell name: inv_homework63_msff
// View name: schematic
V2 (CK 0) vsource type=pulse val0=0 val1=5 period=40u delay=0 rise=1p \
  fall=1p width=20u
V1 (D 0) vsource type=pulse val0=5 val1=0 period=60u delay=0 rise=1p \
  fall=1p width=30u
V0 (vdd! 0) vsource type=dc dc=5
I39 (net7 net4 Qs) inv_homework43_nand_extracted
I38 (Qm net8 net7) inv_homework43_nand_extracted
I37 (Qs net6 net4) inv_homework43_nand_extracted
I27 (Qm net2 net5) inv_homework43_nand_extracted
I26 (net3 net5 Qm) inv_homework43_nand_extracted
I18 (CK net1 net2) inv_homework43_nand_extracted
I36 (net8 net9 net6) inv_homework43_nand_extracted
I25 (D CK net3) inv_homework43_nand_extracted
I40 (CK net8) inv_homework3_inv_extracted
I35 (Qm net9) inv_homework3_inv_extracted
I24 (D net1) inv_homework3_inv_extracted
C0 (Qs 0) capacitor c=100f m=1
simulatorOptions options psfversion="1.4.0" reltol=1e-3 vabstol=1e-6 \
  iabstol=1e-12 temp=27 tnom=27 scalem=1.0 scale=1.0 gmin=1e-12 rforce=1 \
  maxnotes=5 maxwarns=5 digits=5 cols=80 pivrel=1e-3 \
  sensfile="..psf/sens.output" checklimitdest=psf
tran tran stop=300u write="spectre.ic" writefinal="spectre.fc" \
  annotate=status maxiters=5
finalTimeOP info what=oppoint where=rawfile
modelParameter info what=models where=rawfile
element info what=inst where=rawfile
outputParameter info what=output where=rawfile
designParamVals info what=parameters where=rawfile
primitives info what=primitives where=rawfile
subckts info what=subckts where=rawfile
saveOptions options save=allpub

```